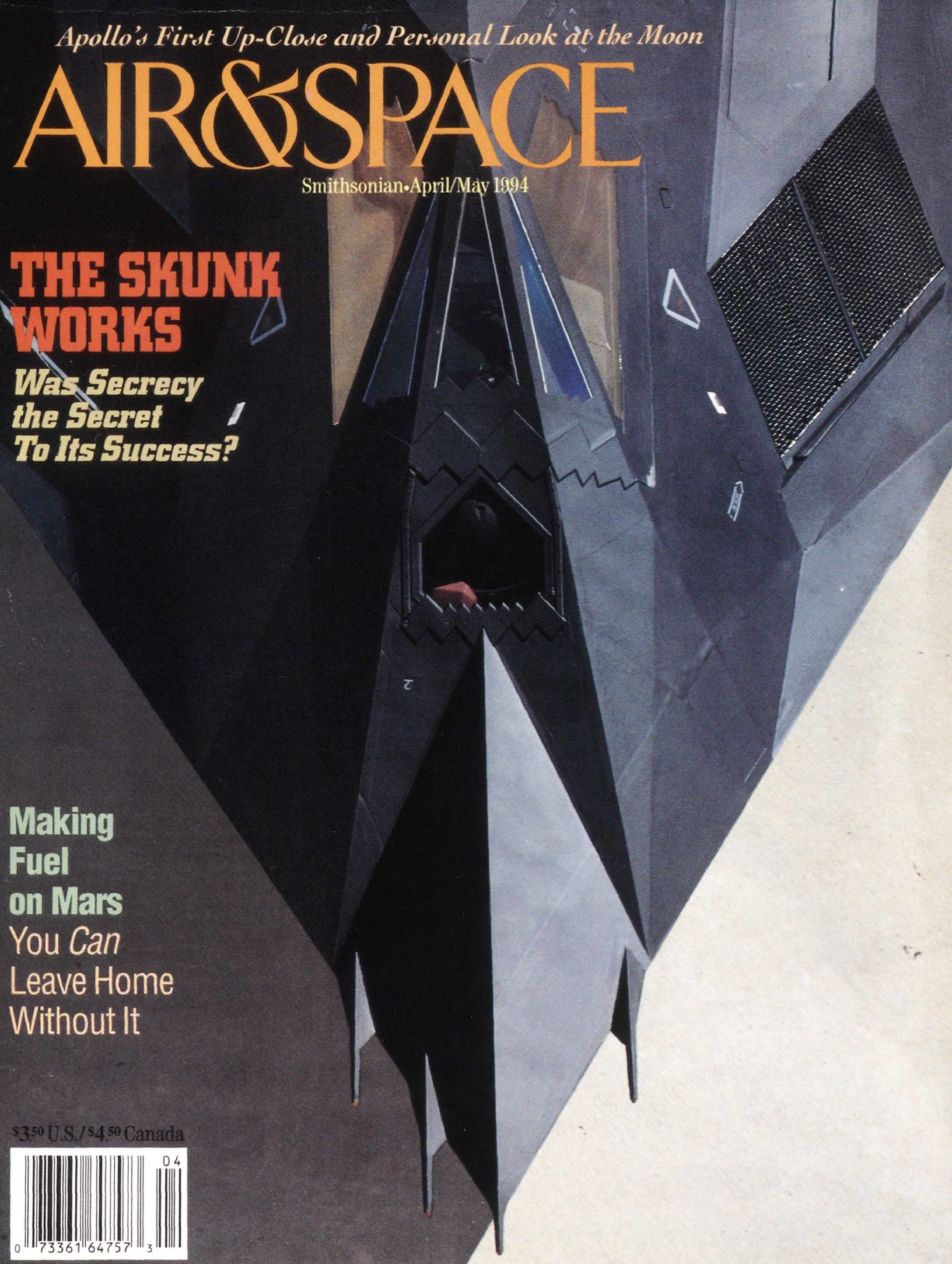

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Cover: Eric Schulzinger's camera captured the F-117 looking its stealthiest.

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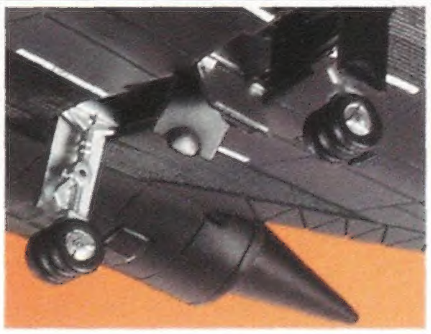

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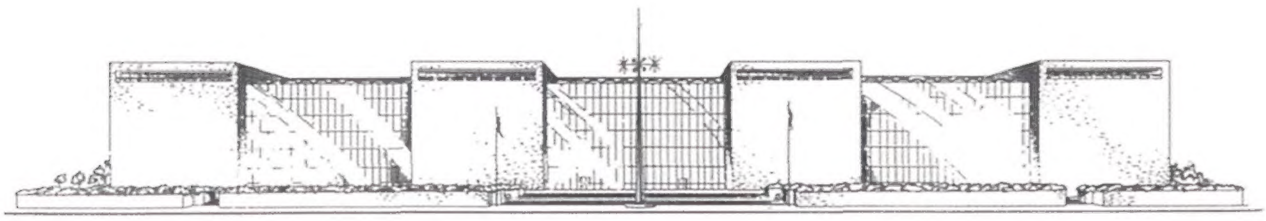

Cultural Fluency

At first glance, technology, language, and culture seem to have little in common. But seeing the connections and adequately responding to them may constitute the biggest single challenge to securing the economic welfare of the United States in the decades ahead.

Here's why.

The United States is a highly technological nation, and its wealth will increasingly depend on global trade. We have a substantial export surplus in the aerospace field, but competition is tough and our market share is always under siege.

In this arena, the young American engineer, who has never acquired a language besides English, never read a foreign magazine or newspaper, and received a technical education that includes little on world history, politics, or economics, is at a disadvantage.

His counterpart, possibly a young engineer from a developing country, will have studied two foreign languages for a number of years by the time he graduates from high school. Part or all of his technical training may have been acquired abroad, perhaps in the United States or Western Europe. And he may regularly read an American weekly.

Technically, the American engineer may have the edge, but in terms of language he is way behind. That may not worry him: he may think he'll make up for the lack by hiring a good interpreter when his work takes him abroad. But that overlooks the crucial link between language and culture.

Speaking a foreign language is not just a matter of translating word for word from the English. In the first place, that's impossible. Words express concepts. They embody myriad images from which they extract a common element and distill it.

Take the quite ordinary English word "hot." The dictionary assigns it a dozen meanings. That complex of meanings will not be the same in any other language. Since words are designed to meet the needs of those who use them, and since people from other countries experience different climates, eat different foods, come from different traditions, and hold different truths to be self-evident, the words making up their languages will differ, and so will their meanings.

Simply put, language reflects culture. We see that when we read a hundred-year-old American document and puzzle over it. Three generations separating us from our own kin have changed our culture and erected a language barrier.

Language is not just a medium of communication, it is a means of gaining insight into the thoughts of other peoples. Speaking another language well means understanding the people who speak it—their body language, small talk, customs, beliefs, feelings for family, recreational preferences, and work style.

Our lack of proficiency in other languages puts us at a singular disadvantage in selling our technologies abroad. While the people with whom we deal speak our language, understand our culture, and thereby gain access to our way of thinking and acting, most of us in America remain baffled by their language, customs, and working habits. Not even the best interpreter can help us overcome that disadvantage.

We hear a lot these days about unfair trade restrictions abroad. And to be sure, these restrictions exist. But without being aware of it, our own beliefs and outlook may have led us to erect other barriers that seem perfectly natural but offend others.

Fluency in even one or two foreign tongues makes us more sensitive to cultural nuances and helps us even when we do have to resort to speaking through an interpreter. We learn to appreciate the ideas and aspirations of other people, and come to befriend them.

Language may be the single greatest new gift we can bequeath to an American youngster in today's world. We should be prepared to equip all our children with fluency, so they may better survive in the world they are about to inherit.

—Martin Harwit is the director of the National Air and Space Museum.

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True to Form

Frank Kuznik's "Blundersat" (December 1993/January 1994) hit close to the mark. Due to its seemingly insurmountable problems, GOES has earned the title (to paraphrase a colleague) "the best weather satellite *on earth.*"

Few will dispute that creating a state-of-the-art imaging system for a brand-new hardware design was technically challenging. To the engineering community, that is stating the obvious. What I find questionable is Mr. Kuznik's implication that NASA needed to send in its "experts" to clean up the situation. In fact, it was NASA that was largely responsible for the situation in the first place. The agency's inability to provide complete, reasonable, and well-defined technical requirements, as well as its management ineptitude, was the root of the GOES fiasco.

Anyone who doubts this has only to look at the handling of the space station program to see exactly the same elements at work. To sell the idea to Congress, NASA promises everything to everybody. Beyond an "artist's conception," the agency has only the vaguest idea how to create the technology. Then there are the contractors. Presented with the opportunity to ride the R&D gravy train, they naturally submit proposals as equally vague and artistic as NASA's request-for-proposal specifications.

Mr. Kuznik quotes NASA's Rick Obenschain as saying: "GOES is a classic

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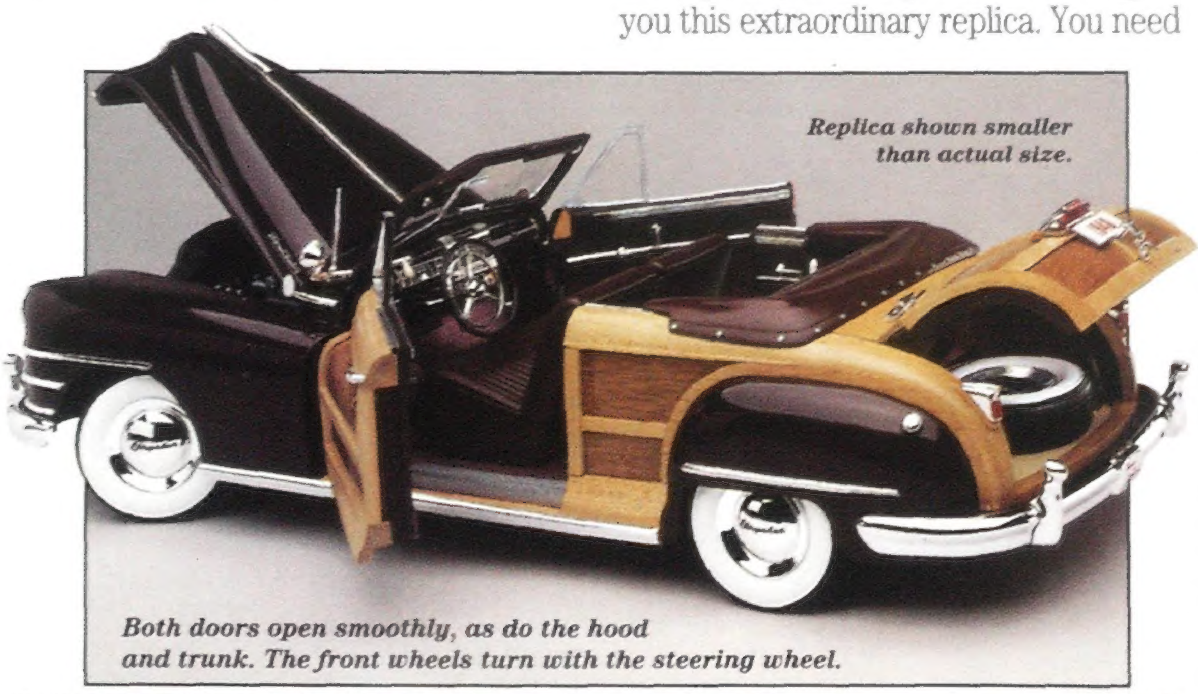


Replica shown smaller than actual size.

Both doors open smoothly, as do the hood and trunk. The front wheels turn with the steering wheel.

study of how not to run a program." But GOES at least has a launch forthcoming; compared to the space station fiasco, the program is a model of efficiency and success. It seems that NASA is doomed to play the role of Sisyphus, forever rolling a rock up a hill only to watch it roll back down.

—George J. Callis
San Mateo, California

Gravity's Oversight?

My vote goes to Michael Minovitch as the man who deserves the credit for pointing out that gravity assist is the most efficient form of space propulsion known ("Gravity's Overdrive," February/March 1994). The problem lies with his boss. Victor Clarke was like so many executives in American commerce and industry today, who, because they are perpetually up to their eyebrows in memos, meetings, and deadlines, do not take time to talk with employees who are brimming over with good ideas.

—Gordon F. Young
Lansdale, Pennsylvania

Final Inspection

In 1980 I made a career change from electronic engineering to quality assurance. One of the first things you learn in quality is that a good inspector or auditor, at his best, will find only 80 percent of the defects, or "squawks," present. If the inspectors in "Your Airbus Is Ready" (February/March 1994) found approximately 50 squawks in the A310, that means they missed 13. Nothing in your story indicated that Aerospatiale was concerned about the number of squawks per airplane, or that it would undertake an analysis of each squawk to find out why the problem occurred and how to prevent it from recurring. Many of us believe that if that A310 had been made in Japan, the director of quality assurance and the president of the company would be looking for new jobs.

I assume that most of the squawks were not life-threatening, but what about those that are? For instance, the leak found in the Airbus' cockpit glass calls to mind the 1990 incident in which a British Airways pilot was nearly sucked out of the cockpit when his improperly installed windscreen blew out. (I was amazed that the Delta pilot in your story, knowing about the Airbus' leak, still took the aircraft to 41,000 feet.) I wish that William Triplett had explained how or why the worker had made the defective seal in the first place, and how the in-process inspector missed the problem. One wonders how many other in-process inspection steps were missed that the customer wasn't able to double-check because the inspection points were not accessible after the airplane was completed.

A few years back, General Dynamics actually produced F-16s without any final inspection squawks. It can be done, and it must be the goal of all manufacturers.

—Max Peterson
Richardson, Texas

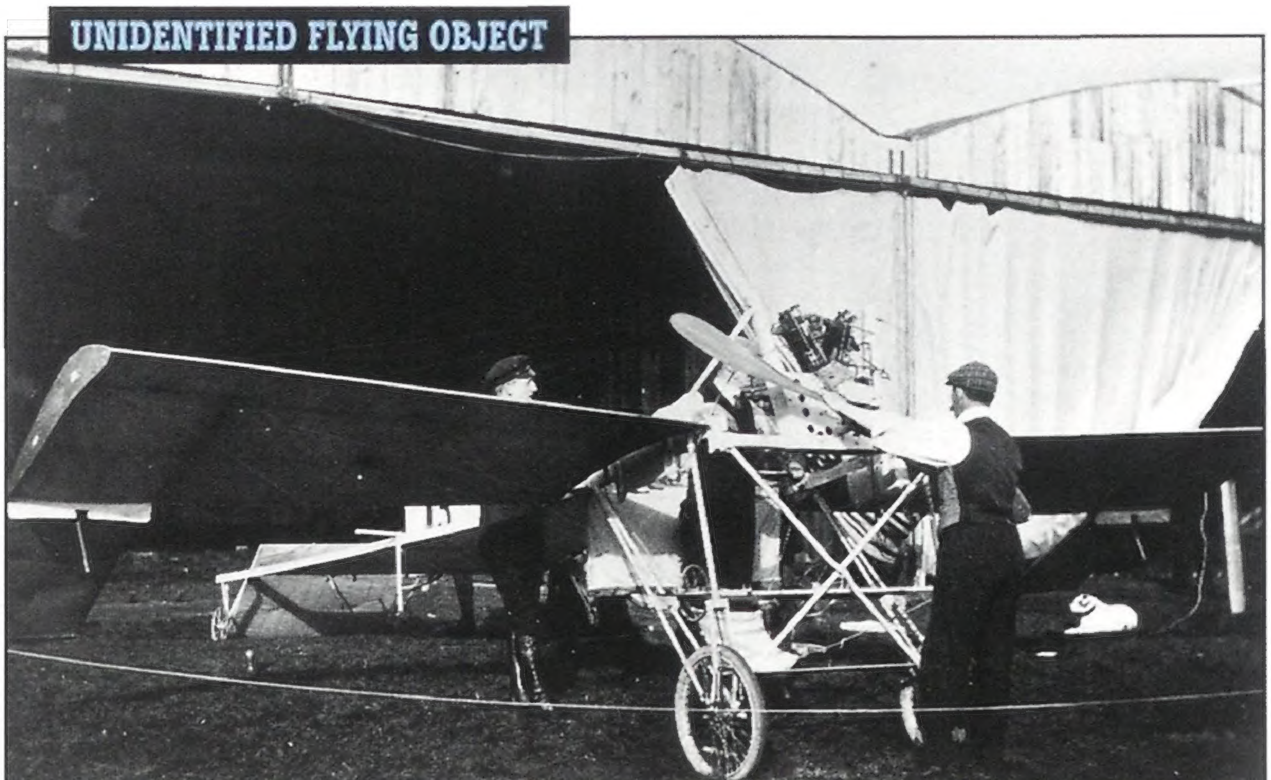
As supervisor of the engine department for Lockheed's L-1011, I had several amusing adventures dealing with foreign inspectors and engineers. The funniest was with All Nippon Airways.

Our department had various ladders and scaffolds, but since we didn't install engines every day, we let other departments borrow the equipment. One day I told my crew to go out to the airplane we were working on and retrieve the ladders, as it was time to put in engines. They returned to report that an assistant foreman had told them, "You mothers can't have this scaffold." He gave no explanation. I immediately sent six men out with instructions to retrieve the scaffold even if they had to push the foreman along with them. I then followed them over to see what was going on. Sure enough, they were pushing the scaffold down the aisle, with the foreman in front trying to stop them.

It was then that I happened to look up at the airplane and see, sitting on top of the wing, an All Nippon engineer. He had been inspecting the number-one engine area, and now he had no way to descend (nor a good enough command of English to call for help). After I got my scaffold back, I brought a ladder to get the very agitated engineer down.

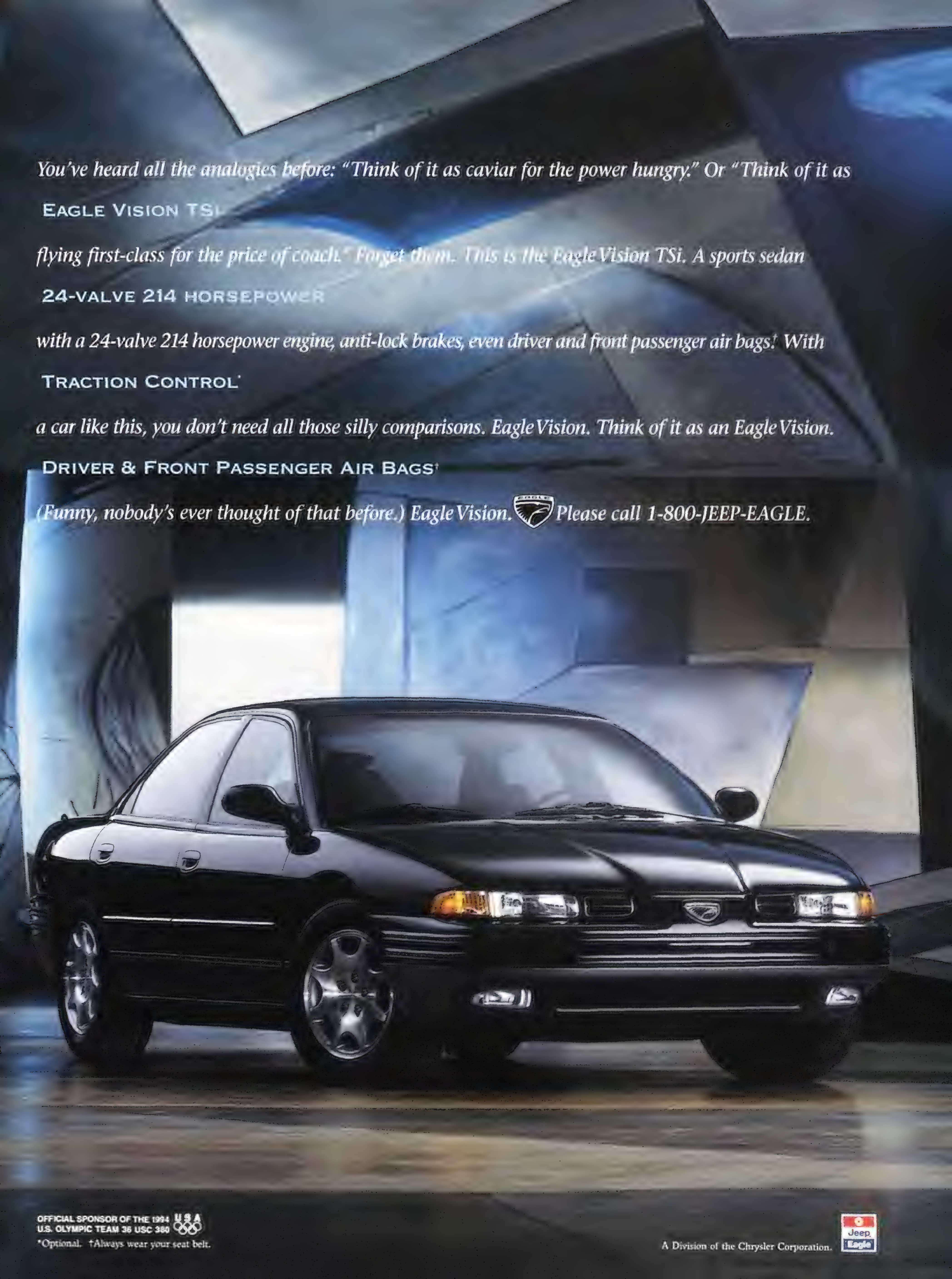
Later, I put a call in to Quality Control for an All Nippon inspector to check out the number-two engine area. After about 40 minutes I figured he had had enough

UNIDENTIFIED FLYING OBJECT



Can you identify this aircraft? From time to time the National Air and Space Museum receives photographs of objects that its archivists cannot identify. This monoplane has unusual control devices at the trailing edge of the wings and horizontal tail surfaces. On the rudder there appears to be a number, possibly 13, suggesting participation in a race or other competition. The pilot apparently reclined in the hammock hanging far below the engine. Based on the uniform of the man standing aft of the wing, the archivists believe that the craft may be German. If you can solve the mystery, write to: Letters, Air & Space/Smithsonian, *370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024. Please type or print clearly, and include your daytime phone number.*

Last issue's UFO has yet to be identified.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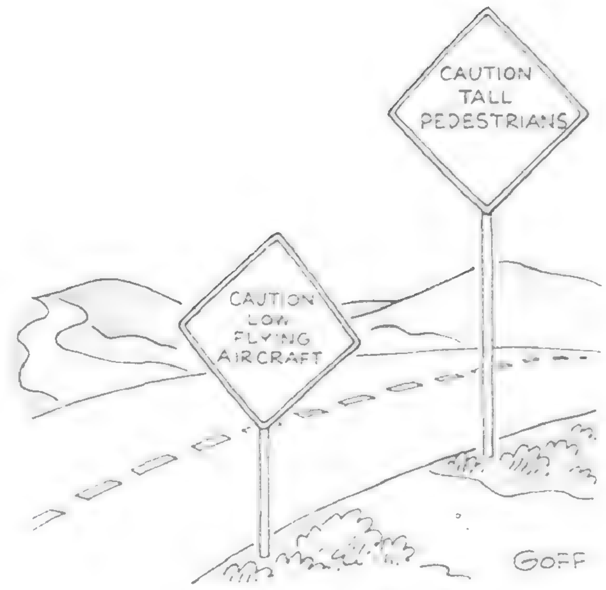
time, and I started up the scaffold. As I reached the engine area, I saw that the inspector was the same man who had been stranded on the wing earlier. When he recognized me, he began exclaiming "Okay! Okay!" and stamping just about everything in the inspection log.

Afterwards, in the company of an interpreter, I found out the inspector had been afraid that I had come up the scaffold to throw him off. We were able to straighten it all out over a cup of tea.

—Hubert F. Cooper
Bonne Terre, Missouri



The Fall of the Eastern Empire

Reading "Life After Eastern" (December 1993/January 1994)I was surprised to see that so many people who had worked at Eastern left the industry or couldn't find work. As a mechanic with the airline, my experience was quite different. I worked in Kansas City, Missouri, with a total of 30 mechanics, at least 25 of whom are still A&Ps (airframe and powerplant mechanics) and many of whom are better off today than they were with Eastern. Many of us saw the end coming in late 1987 and started seeking employment elsewhere. All the others left when the union went on strike. Only two mechanics returned to the "new" Eastern, and they are now out of the industry.

All the people in your article, on the other hand, stayed until the bitter end, and it appears that they paid dearly for that by not being able to find work within the industry. In addition, with the exception of the pilots, everyone interviewed was an administrative or clerical employee. A&P mechanics may have better luck finding work due to the nature of their skills.

I enjoyed working for Eastern very much, but I knew, as did many of my fellow mechanics, that the end was near and it was time to move on.

—Cliff Carlino
St. Louis, Missouri

Strong Feelings About Captain Stewart

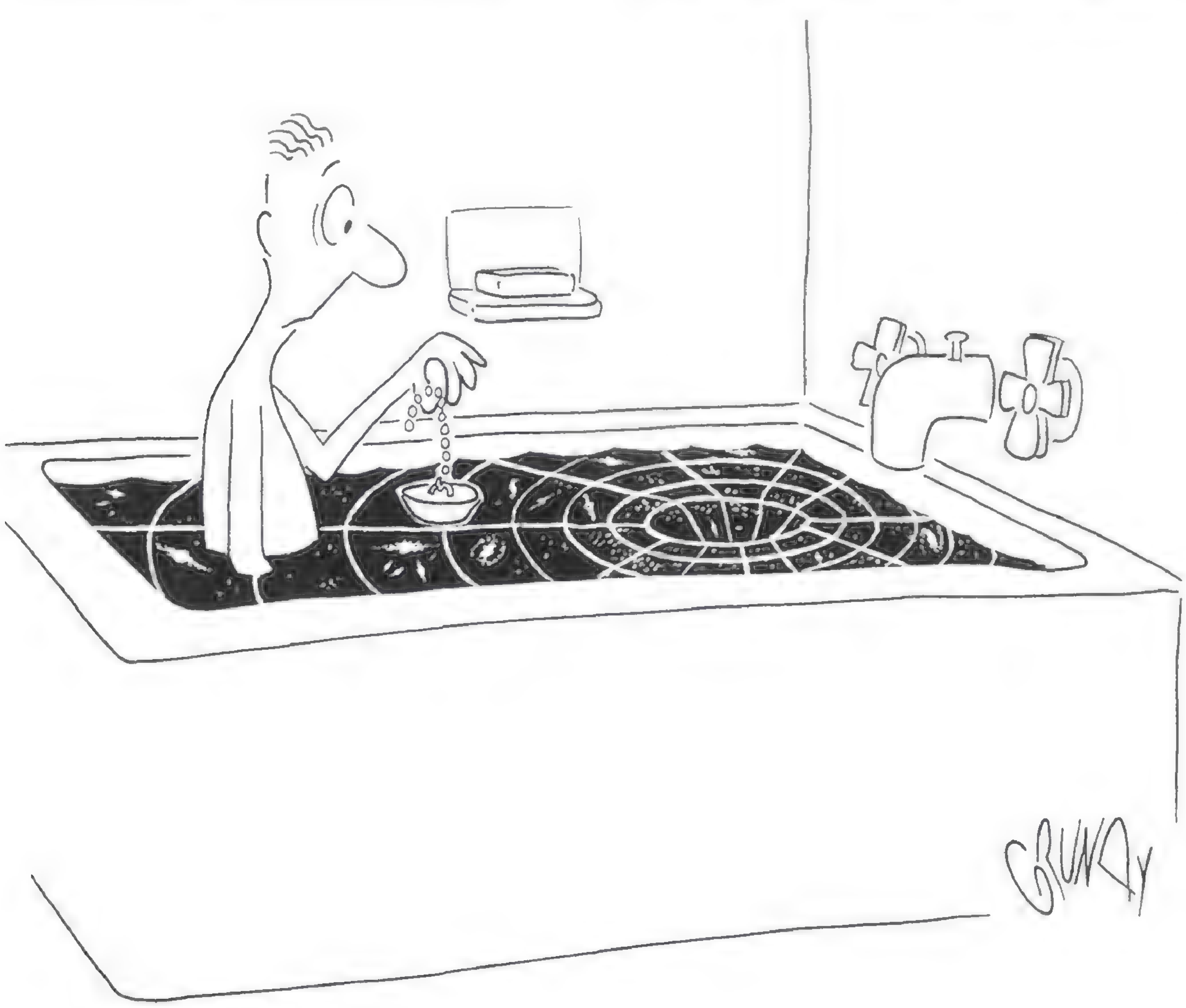
I must take exception with the gist of "The November Oscar Incident" (February/March 1994). While I agree that Glen Stewart was probably railroaded in the civil court system, I object to the suggestion that the airlines set him up for the incident.

As an airline pilot with 27 years of experience (including 16,000 hours of flying), I have never felt pressure from management to do the things Stewart did. In fact, the pressure I feel is to take whatever I deem the safest course of action, and my airline will back me to the fullest. I have turned down airplanes I believed were not fit for flight, diverted to alternate airports for a dozen different reasons, and missed approaches for reasons varying from windshear to an inability to see the runway. I have yet to be asked why.

If any of my crew members ever became as ill as the crew members on Stewart's flight, I would terminate the trip on the spot. I would absolutely never attempt an approach without all crew members being qualified. Furthermore, our guidelines on terminating an approach are extremely clear. Below an above-field elevation of 500 feet, we are talking about a deviation from glide slope and localizer of less than a third of a dot. If we are not within those parameters, we must go around. We do not have a choice.

As a fellow airline captain, I think I understand what Stewart was thinking. He was trying to salvage a lousy trip, and he succumbed to what we call "get home-itis." I suggest that this malady has caused more accidents than any other factor.

—Captain Jerome F. Keefe
United Airlines
Columbia, Maryland



At the conclusion of his article, Stephan Wilkinson comments: "In the end, I rejoined the Stewart camp, embarrassed to admit that I too would never have understood the pressures under which an airline captain operates if friends and acquaintances who do it every day had not made it obvious to me…." Wilkinson misses a fundamental point. Yes, the pressures are great—even, at times, crushing. But we do not expect ordinary people to become airline captains. If an individual is unable to withstand the pressures, which include the conflict between safety and profitability, he or she should step down.

An airline captain must be ready to put his or her job on the line to protect the passengers from the airline. But I doubt that the choice Stewart faced was so extreme; I suspect that had he diverted to Manchester or even Frankfurt, the most he would have endured would be a verbal reprimand. Furthermore, if British Airways' chief pilot was worth his stripes, he would have commended Stewart on his judgment and said as much to the airline's management.

Regardless, I think it's safe to say that had Stewart made such a decision, he would not have been demoted to first officer, forced to resign from his airline, and convicted in court of endangering his passengers.

—Dean Eppler
Houston, Texas

I'm a 25-year-old pilot whose career has just begun to take off. I, much like Captain Stewart, have spent long hours peering through airport chain-link fences with the hopes of proudly showcasing my flying talents for a major airline.

To be quite honest, after I read "The November Oscar Incident," my dreams have begun to "slip the surly bonds," as one young airman so eloquently put it. Is it possible that our proud and powerful U.S. airlines could be as cold and malicious as British Airways appears to have been in this case? To let an experienced and judgmentally intact captain be thrown to the wolves disgusts and frightens me. Will I be labeled a criminal one day for doing what my heart and what all of my experience tell me is the right thing to do?

—Christian G. Sava
Stamford, Connecticut

"We know your baggage is in the Pleiades. We just don't know where."

Mr. Wilkinson writes: "There are no merit promotions in the cockpit. Pilots move up solely on the basis of seniority in the company." He adds that, as a result, "an ex-Blue Angel with golden gloves" could end up a flight engineer on a 727, while someone who started out as a civilian flying Cessnas might, having flown for 30 years with an airline, end up the captain of a 747.

The implication that a former Blue Angel would be a better captain than a pilot who has logged countless thousands of hours with a global airline is ludicrous. Who better to command the world's most capacious passenger transport than one who has spent his professional lifetime in airline operations? Although seniority provided him the opportunity to attend 747 captain training, Stewart still had to pass the rigorous ground school training and the Civilian Aviation Authority's written and oral exams, and he had to earn his 747 type rating in a simulator test. Wilkinson should have written: "Every promotion in the cockpit is based on merit, seniority allowing."

—Second Officer Morgan M. Fischer
Trans World Airlines
Williamsburg, Virginia

As an Air Force pilot, I was generally spared the pressures of misplaced passenger displeasure and airline economics, which were certainly major factors in Captain Stewart's decisions. But all pilots labor under the aeronautical axiom "It's usually not the one problem that gets you in trouble; it's the problems ganging up and overwhelming you."

One night, a series of circumstances forced me to land a B-29 out of a ground-controlled approach in a blinding snowstorm. My crew chief was aboard and I had him up front to help the copilot look for the runway lights during the approach. But even if we had been able to see through the storm a few seconds before touchdown, the lights turned out to be buried in snow.

Harv works the red shift.

After we landed and the crew chief realized we had stopped rolling, he leaned over and drawled in my ear, "Cap'n, I ain't seen no damned lights till yet."

These are episodes that should not be judged by anyone who hasn't been there.

—Lt. Col. James L. Brewer
U.S. Air Force (ret.)
Grant, Alabama

While having no fundamental disagreement with the conclusions reached by Stephan Wilkinson in "The November Oscar Incident," we do believe that some comments from the British Air Line Pilots Association are appropriate to complete the story.

Mr. Wilkinson refers to the fact that "much of the trial revolved around arcane legal points, and Stewart himself was never called to testify on his own behalf. His BALPA lawyers believed that he would only continue to raise irrelevant issues, and that Stewart would have been better off pleading guilty and allowing them to seek mitigation of the charges." BALPA has no intention of breaking the confidence of the consultations between Captain Stewart and any of his advisors but we do believe that Glen, if he were here, would wish your readers to be aware of his own views as stated in his June 29, 1991 letter to BALPA.

In that letter Glen stated that "BALPA's tremendous support over twenty months of trouble has been much appreciated.... BALPA technical, financial, legal and moral support were of the highest quality.... My ex-colleagues who are not BALPA members tread alone a dangerous and treacherous path."

We are sure you will understand that such quotations are selective, but (we can assure you) they do accurately set out Glen's own views. We doubt whether anyone—apart from his family—was more upset than his many friends in BALPA about the events leading up to Glen's suicide in 1992.

We end with one further quote from Glen's letter: "The CAA now probably deeply regret their action, it has dried up the flow of safety information from the crews. Government ill-thought out edicts consequently achieve exactly the opposite result to that desired. A British Court is not the correct forum for 'an immensely technical complex case.' " With sadness and respect, we agree.

—Captain W. Archer, Chairman
Sir Alexander Glen, President
British Air Line Pilots Association
Harlington, United Kingdom

Indestructible Insects

In "The Great Lunar Quarantine" (February/March 1994) Brian Duff states that the only discernible effect lunar material had on people, plants, or animals was the speeding of plant growth. However, he neglected to mention one other finding. The Baker Histology Laboratory prepared microscopic sections of insects (we called them "moonbugs") that had been allowed to crawl over the moonrock, and then we sent the slides to entomologists at the U.S. Department of Agriculture for study. The findings: lunar material had no effects on insects either.

—Charles C. Baker
Baker Histology Laboratory, Inc.
Great Falls, Virginia

Correction

February/March 1994 "Fierce to Win": Campbellsport, Wisconsin, is 25 miles west of Lake Michigan, not east.

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SMALL WONDER

NAVAL RESEARCH LABORATORY

The scene inside Allied Signal Aerospace, located a few miles south of the Pentagon in Alexandria, Virginia, makes you wonder what's going on in the other unremarkable brick buildings in the neighborhood. Allied Signal's Technical Services Corporation is mission control for a once-secret Ballistic Missile Defense Organization project; inside the building, behind a deceptive blank facade, a half-dozen spacecraft controllers are watching computer screens in a darkened room.

They are monitoring Clementine, the pint-size probe that was launched last January to make multispectral images of the moon. Developed for the BMDO by the Naval Research Laboratory, Clementine didn't start out as a moon mapper; it was originally a Star Warrior. The spacecraft is testing advanced miniaturized sensors that the old Star Wars program wanted to use in space to track missiles launched toward U.S. targets. When Clementine is finished with the moon, it will perform the part of its mission for which its optics were designed: searching for and tracking a cold object hurtling through space—in this case, the near-Earth asteroid Geographos.

"The closing velocity would be about the same," says mission manager Colonel Pedro Rustan. His team estimates that the relative velocity at which the two objects will charge toward each other will be almost 25,000 mph. Rustan sketches the parabolic flight path of an imaginary intercontinental ballistic missile—"Here's Baghdad; here's Washington," he says, making little circles at each end—and indicates the portion of the trajectory where its temperature, behavior, and velocity would be similar to those of an asteroid in deep space.

Clementine will have its closest encounter with the asteroid on August 31, when the two objects will be 60 miles from each other. At that point Clementine will have only two minutes to collect images. But with its high-resolution ultraviolet/visible charge-coupled display camera, two infrared cameras, and laser imaging and ranging device (LIDAR), the probe is expected to get more than 2,000 images, some with a resolution of about 15 feet, and store them on its solid state recorder. The mention of the recorder makes everyone in the room smile.

"No moving parts," gloats Stewart Nozette, a BMDO scientist and Clementine's deputy mission manager. "It weighs under eight pounds and has 2,000 megabytes. That's hundreds of PCs."

After learning that BMDO intended to go after an asteroid, NASA signed on. It formed a science team, headed by noted Apollo geologist and asteroid hunter Eugene Shoemaker, designed the flight path to Geographos, and provided support with its Deep Space Network. The Naval Research Laboratory did the rest.

NRL program manager Paul Regeon and the BMDO managers in the conference room take turns ticking off the mission's virtues. The spacecraft sports the lightest solar cells ever flown. All of its systems—inertial measurement units, reaction wheels, batteries, computers—have the weight savings and reliability made possible by the last decade's advances in solid state electronics. Without fuel, it weighs 500 pounds, and at $75 million, Clementine cost half the amount NASA has proposed for one of its "smaller, cheaper, faster" Discovery planetary missions.

The litany is interrupted when a mission controller raps on the window separating him from the conference room and points at two monitors mounted high on the conference room wall. Star fields cascade down the screens, a line of pixels at a time. Clementine adds its own contribution to the chorus singing its praises: it's working.

When the litany resumes, Rustan points out that Clementine is the first Department of Defense mission in deep space. It is also the first defense department mission dedicated to Gerard K. O'Neill, the Princeton physicist who popularized the notion of space colonization, beginning with a 1974 paper in *Physics Today*. "That article kept me

from going to medical school," says Nozette, who worked on the Pioneer Venus mission before he left NASA for the defense department. "[O'Neill] was one of our inspirations. We wanted to go to places where humans would go, to places that might eventually support humans." It's an unusual objective for the military, but Nozette says, "It's what the military has always done in peacetime—prospecting."

—*Linda Shiner*

UPDATE

Reprieves

Last January 31, NASA came up with $1 million to keep the McDonnell Douglas DC-X alive through March ("Single Stage to...Where?" February/March 1993). The funding will keep the Delta Clipper experimental rocket out of mothballs after Pentagon officials refused to continue funding it. NASA and the defense department will work out a plan for further DC-X testing.

The NASA-sponsored Search for Extraterrestrial Intelligence, which began in October 1992 and lost funding a year later ("SETI Takes the Hill," October/November 1992), has received $4.4 million in corporate and private donations. The amount is about half of what is needed to continue the search through mid-1995.

DAVID CLARK

The Shuttle of My Aunt is on the Launch Pad

Live on TV last February 8, Sergei Krikalev, the first cosmonaut to be launched on a U.S. spacecraft, sent greetings from the shuttle *Discovery* across 5,700 miles of space to fellow cosmonauts aboard the Russian space station Mir. Arranged by ABC's "Good Morning America," the chat was as unceremonious as it was historic, thanks to a language barrier.

"Greetings. I hear you loud and clear. Can you hear me?" said Krikalev in his native tongue.

"Why are you speaking English to us?" said Valeri Polyakov. "Have you forgotten Russian?" The Mir cosmonaut was then told he had been listening to the translation provided for the rest of the shuttle crew and U.S. TV viewers.

Russian, of course, is the operational language aboard Mir, and agreements formalized by the two nations last December specify that the five Americans scheduled to visit Mir in the next few years will speak it.

The first is Norman Thagard, a four-time mission specialist who is the only astronaut considered fluent in Russian. "I read Russian really well," Thagard said last February before leaving for Star City near Moscow for a year of training. "Speaking is lagging behind."

Thagard has plenty of company in learning his Cyrillic ABCs now that the United States and Russia have decided to build a space station together. At least 200 people are enrolled in Russian language and culture classes being taught at or near the three shuttle flight centers—Kennedy in Florida, Johnson in Texas, and Marshall in Alabama. That's about one percent of NASA's civil service workforce. The number includes about 50 astronauts, roughly half the active corps.

Enrollment at Kennedy swelled 50 percent over the limit last January. Enrollees are primarily engineers, says employee development specialist James Norman. "They're the ones that actually get involved with [shuttle and payload] integration and will probably be working the very closest with their Russian counterparts." A primary concern is making sure technicians understand weights and measures and can decipher instructions—often cryptic even in English—that come with cargo. The idea of bilingual space workers isn't new, points out Frank Nesbit, Kennedy's chief of human resource development. "We handle a lot of international payloads, so people are all the time going out and taking Berlitz courses...in Japanese, Italian, German," he says.

Despite the potential for a lasting relationship between the two nations, some students have found a long-term language commitment difficult. The classes at Johnson emphasize the spoken language in 30 hours of role-playing. "You're not coming out with a whole lot," says human resources development specialist Susan H. Anderson. "You're still a beginner." Kennedy students learn to speak, read, and write a limited vocabulary. "You can practice grammar using words like *rocket* and *shuttle* instead of *table* and *chair* and *lamp*, but that's the very most you can get," admits Andrei Belyi, a Moscow State University linguist and visiting professor at Brevard Community College in Cocoa, where the classes are held.

Even though NASA pays the tuition—about $100 a head at Kennedy and double that at Johnson—dropout rates are high. Only half the Kennedy students persevere, says Belyi, because learning the language takes more time and effort than they expected. "When you realize that they come to class just to learn to say *hello* and *goodbye* and to read *NPO Energia* in Russian," he says, "and that's the very most they take, this is frustrating."

—*Beth Dickey*

UPDATE

Legendary Logo

The Pan American logo (Soundings, February/March 1994) may fly again, this time on charter flights to Europe. Two Maryland businessmen bought Pan Am's blue globe logo in bankruptcy court last December for $1.3 million and have established Pan Am Charters, which will fly from Baltimore to Europe several times a week and eventually to Latin America.

In a Word

Unless you subscribe to an astronomy magazine, you probably haven't seen the glorious photograph below, taken with the repaired Hubble Space Telescope. It reveals a fascinating cosmic drama, but it was not released to the press on January 13, when administrators and bureaucrats trumpeted the success of the repair mission at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

In 1841 the star Eta Carinae, 150 times more massive than the sun, suffered a convulsive explosion and briefly became the second brightest star in the night sky. Hubble's improved vision now reveals a rapidly expanding shell of gas around the star while two lobes of matter blast out from the hole in an encircling torus of dust that remains unseen even to the telescope's marvelous eye. The mechanism of the explosion appears to be shockingly different from what scientists

NASA

expected, and there is plenty to wonder about and study now that this violent outburst is visible.

The officials who announced the results of the Hubble test did not, however, touch on this information. Instead, everyone on the podium offered catchy, worn-out phrases, carefully orchestrated to sell Congress and prove to skeptics the value of astronauts performing complex tasks in space. The subject of the panel was the space telescope, but the message was clearly the space station.

"The trouble with Hubble is over," declared U.S. Senator Barbara Mikulski in the panel's best candidate for a sound bite. "Because of the repair work on Hubble there is now a confidence that the space station can be built." Jack Gibbons, assistant to the president for science and technology, said that the instrument "will enable us to push back the unknown," an unusable quote for most science reporters in the audience since everything they write about is in some way an attempt to push back the unknown. "It has an unprecedented capability to understand the unknown and enrich our spirits," he continued.

Not until the following day, at a more sparsely attended briefing, did astronomers speak to the press about the images themselves—among them, this clear view of a shattering star.

The widely publicized before-and-after pictures of astronomical objects released at the press conference were spectacular, but one could not help reflecting on what was being overlooked. One of the officials on that panel made a statement that epitomized the conference's hype. There was "only one word," he said, for the success of the Hubble repair mission. That one word: "Absolutely incredible."

—*Gerrit L. Verschuur*

UPDATE

Bodies of Evidence?

The General Accounting Office has been called in to investigate a possible coverup of the circumstances of a mysterious 1947 crash near Roswell, New Mexico ("Aliens in the Basement," August/September 1992). At the time, the Army Air Forces said the crash remains were from a downed weather balloon. The investigation was initiated after Representative Steven Schiff of New Mexico complained to the GAO that the defense department had been uncooperative when he inquired about the incident on behalf of Roswell-based constituents.

BSR

Engine quit? Ballistic Recovery Systems' parachutes can cushion an impending impact for small general aviation aircraft. Company president Boris Popov got the inspiration for the $5,500 airplane parachute in 1977 after a powerboat towing his hang glider accelerated too fast and pulled the glider's wings apart. After a 15-year effort, Popov's Minnesota-based company won Federal Aviation Administration approval for its rocket-deployed parachute.

Airport Lite

An ultralight is an airplane distilled to its purest form. So it's fitting that the Brian Ranch Airport—one of the few Federal Aviation Administration-approved facilities developed specifically for these elementary flying machines—should be an airfield reduced to its bare essentials: air and field, plenty of both, not much of anything else. As founder and owner Jack Brian says while surveying his one hangar and a giant hole being dug for a septic tank, "You'd have to call it a bootstrap operation, wouldn't you?"

A genteel 67-year-old British expatriate who always wears a tie, Brian is doing his best to carve an aviation oasis out of the scrub of Southern California's high desert. Last year he secured a permit to keep 30 aircraft on his 40-acre site in Llano, south of the dry lakes of Edwards Air Force Base. Although he has only 14 tenants so far, his airport now boasts two 1,000-foot runways, a flight school with two instructors, materials for a second hangar and plans for a third, as well as a fractious poodle and a golden retriever.

Brian Ranch has the friendly, easygoing character of the small country airstrips that are fast disappearing from the aviation landscape. "What I really wanted to do was build an airfield that

Every man over 50 should take this

PROSTATE TEST

Please answer the following questions:

YES	NO	
☐	☐	Do you urinate often, especially during the night?
☐	☐	Do you have trouble starting your urine stream?
☐	☐	Do you have a weak or interrupted urine stream?
☐	☐	Does it feel like your bladder isn't emptying completely?

Please detach and take to your doctor.

If you answered "yes" to any question, you should see your doctor. You may be experiencing the symptoms of a condition called benign prostatic hyperplasia (BPH), which is an enlargement of the prostate gland.

Affecting one out of three men over the age of 50, symptomatic BPH can be caused by a *tightening* of muscles inside the prostate. These tightened muscles can slow the flow of urine, leading to the kinds of urinary symptoms described above.

There are three basic treatment options for symptomatic BPH: "watchful waiting," which entails having regular checkups over time; surgery; and medication.

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could support a flying club—a group of people who like to fly and like to talk about flying," Brian says. "I'm not expecting to make any money out here. I'd be satisfied if we just broke even."

Brian spent much of his childhood traipsing around England while his father built temporary airstrips during World War II. As a teenager he worked at the Royal Aircraft Establishment, and later as an engineer in Britain, New York, and finally Los Angeles. When Brian retired from Hughes Aircraft in 1987, he was a senior scientist specializing in satellite communications.

An avid pilot—he owns three airplanes and two ultralights and flies his Piper Tomahawk down to Santa Monica every week—Brian had long dreamed about building an airport catering to general aviation. "I never really thought, quite frankly, that [satellite] communications would last as long as it did," he says. "I assumed somebody would invent something that would put me out of a job." Instead, ironically, Brian climbed the corporate ladder while the general aviation market crashed and burned.

Brian's vision might have done the same. "But when ultralights started coming on," he recalls, "I thought, *Hey, that's the way to go.*" Although ultralights aren't subject to the stringent FAA regulations that apply to powered aircraft, Brian was determined to build an airport sanctioned for light airplanes. The FAA was eager to work with him but Los Angeles County officials weren't. "They were worried about jets taking off and landing here," he says. "I kept telling them that it wasn't going to be that kind of airport."

No, it's not the kind of airport with a control tower and duty-free shops—or bathrooms (at least not yet). But it's got a certain raw charm and a lot of potential. As Brian puts it, "This is a place for people who fly just for the fun of flying."

—Preston Lerner

STEPHEN J. PRINGLE

UPDATE

Sizing up Soyuz

NASA engineers want to take a look at the 1990 Soyuz capsule sold to an anonymous collector at the Sotheby's auction of Soviet space artifacts last December (Soundings, February/March 1994). Since NASA chose the Soyuz as an emergency ferry for the space station crew, space agency engineers have made several trips to Russia to examine hardware. However, they say they would like a close look at the Soyuz capsule to confirm data and measurements received from the Russians. The National Air and Space Museum is negotiating with the capsule's new owner to bring it to the Museum for a NASA inspection.

Wannabes Online

It's one of the most exclusive jobs in the world. Of the 2,700 people who have submitted applications for the next round of U.S. astronaut selections, NASA expects to choose only 15 to 20. It's no surprise that some of the hopefuls might want to band together for consolation. Last October one applicant, Geoff Rutledge, a 39-year-old physician, pilot, hang-glider, and Ph.D. candidate, started an informal discussion group on the Internet computer network for people who aspire to be astronauts.

Electronic mail messages sent to Rutledge's "astronaut candidates" list at Stanford University are automatically forwarded to everyone else in the group. The 120 participants include total no-hopers ("I'm not fit, I can't scuba dive, and I can only fly flight sim[ulator]s," admits one) and kinda-wannabes like Jeff Moersch, an astronomy graduate student at Cornell who writes, "I've had the ol' application sitting on my desk now for about a year," as well as serious contenders who have been called to Houston for an interview.

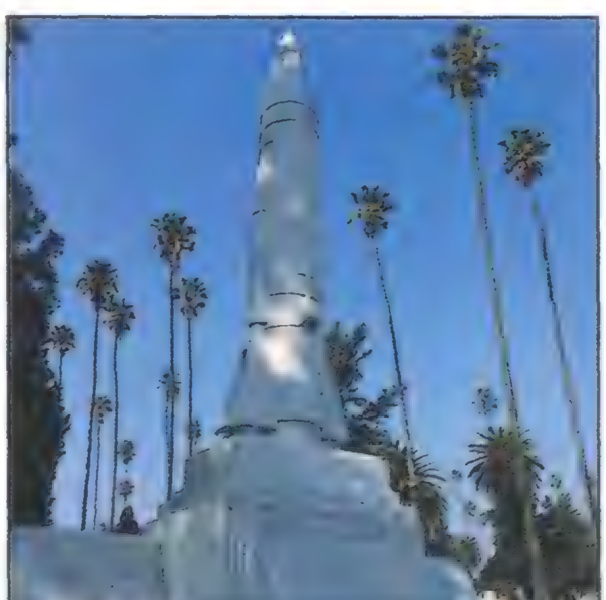
Discussion topics cover speculation about when the temporarily suspended selection process will start up again (maybe this spring), whether cooperation with the Russians will help or hurt their chances (no one's sure), and whether the people in the astronaut selection office are monitoring the discussions (they aren't).

The hopefuls worry about their job qualifications, flight experience, and health. Forty-year-old Monica Halka, a Ph.D. in laser spectroscopy who's also a rock climber, diver, and flight instructor with 700 hours of pilot-in-command time, says, "My main concern is that I am pushing the age limit." Indeed, the group is painfully aware of the long odds and stellar competition. Steve Robinson of NASA's Langley Research Center, who was a finalist before the selection process stalled, writes that his fellow interviewees were "the most impressive, accomplished humans I have ever seen up close, and I kept wondering what kind of mistake had occurred to include me in the group."

Remarks can be surprisingly candid. "The psychological tests were, to my mind, stupid," writes John Sotos, who was a finalist in 1989. "The psychiatrist's three-hour interview was completely transparent to anyone who has been through medical school. But let's face it, NASA has five days to decide if you, a total stranger, are the type who is going to embarrass them and the country in orbit or, perhaps worse, on 'Nightline.' You can't blame them for trying everything."

Even with careers and egos at stake, subscribers manage to keep their humor. One writer told of a fellow candidate who joked that if astronaut candidates were called "ass-cans" (the nickname for rookie astronauts during their probation period), then the astronaut hopefuls must be "ass-hoes." The name has started to catch on.

—*Tony Reichhardt*



CHAD SLATTERY

Rarely is a cemetery a tourist attraction, but in Hollywood, visitors to the graves of Rudolph Valentino, Cecil B. DeMille, Tyrone Power, and other luminaries can also see a detailed replica of the first Atlas missile. Marking the burial site of publisher and space enthusiast Carl M. Bigsby, who died in 1959, the monument is inscribed with the history of the Atlas. A headstone for his wife reads:

Constance W. Bigsby
Too bad...we had fun
1914–

THE FALSE PROMISE OF AERODROME NO. 5

The Langley Aerodrome No. 5 is pretty small for an airplane, with the peculiar feature of having two 13-foot, eight-inch wings placed one in front of the other on the spindly fuselage. A mistake following the plans? It's almost as though the builder didn't know what an airplane is supposed to look like.

In 1896, no one did. On May 6 of that year, Samuel Pierpont Langley's Aerodrome No. 5 became the first powered, heavier-than-air vehicle to achieve sustained flight. The unmanned craft is currently being restored at the National Air and Space Museum's Paul E. Garber Restoration, Preservation and Storage facility in Maryland. Bernard Poppert is the technician overseeing the restoration, and parts of the B-29 *Enola Gay*, one of his other projects, lie nearby. Like the other technicians at Garber, Poppert is a sort of time-traveling mechanic; he has occasionally worked on satellites and early aircraft at nearly the same time.

The Aerodrome No. 5 was last restored in 1976 in preparation for the Museum's opening. Since then, the linen-like fabric it was re-covered with has deteriorated to the point where restoration is again necessary. This time the airplane will be covered in silk, the material Langley originally used. Silk deteriorates more rapidly than other materials, but because the No. 5 will now be displayed in the windowless Early Flight gallery, rather than its old home in Milestones of Flight, the life of the restoration should be extended, says Peter Jakab, an aeronautics department curator.

The biggest problem with the current restoration has been the deterioration of the airplane's wood. Because the original wings are so badly decayed, Poppert is crafting exact duplicates. "We're going to crate the original wings up and store them," says Poppert. "The original tail and the original wooden props will stay with the aircraft. They're in pretty good shape."

The fuselage, which is constructed of thinly milled steel tubing, is also in good condition, though a few cracks and kinks had to be repaired. The engine's tiny steam cylinders no longer hiss, but the whole mechanism of precision drive shafts and beautifully milled gears still turns freely and eagerly after almost a century. Apply a little finger pressure and the propellers turn, ready to bite into the air again.

While researching the aircraft, Poppert noticed that some of the launching system support pieces were either missing or not correctly attached to the airplane, so he is striving to restore the No. 5 so that it can be more accurately displayed. Photographs of the aircraft in 1896 are being studied and some of the missing launch attachments are being duplicated, though they'll be replaced with the original pieces if they are ever found and are usable. "We've been looking at Langley's kit—what's left of his equipment—as much as we can, without pulling it out of storage," says Poppert.

Looking at the modest little Aerodrome No. 5, it's hard to believe it was once part of a great aviation tumult. Langley was the third secretary of the Smithsonian Institution and received financial backing from the Institution as well as a workshop in the Smithsonian Castle to develop his series of Aerodrome aircraft. The affiliation would eventually entangle the Smithsonian in an angry dispute over Langley's place in history.

Both of the Aerodrome No. 5's flights were witnessed by Alexander Graham Bell, who gave this glowing account of the first flight: "On the occasion referred to, the aerodrome at a given signal, started from a platform about 20 feet above the water and rose at first directly in the face of the wind, moving at all times with

NASM

MARK AVINO

In 1896, the Aerodrome No. 5 was launched from a spring-actuated catapult atop a houseboat on the Potomac River (right). Today the craft is being restored by Garber technician Bernard Poppert.

remarkable steadiness...."

The triumph of the No. 5 fueled Langley's hope of building a manned version. Firmly convinced that the next aeronautical success would also be his, Langley began work on a full-size craft, which was called the *Great Aerodrome*. It was powered by an advanced engine designed by Charles Manly, who doubled as the pilot. But because Langley simply enlarged the scale of his models, the *Great Aerodrome* was fragile and unairworthy.

In 1903 Manly made two flight attempts. Both times the frail craft crumpled and fell into the Potomac. On the second try, Manly almost drowned before freeing himself from the wreckage. Langley fared no better: the widely publicized failures made him the subject of derision that ended only with his death in 1906.

Controversy followed. Despite the failures, in 1918 the Smithsonian displayed the reconstructed *Great Aerodrome* as "The first man-carrying aeroplane in the history of the world capable of sustained free flight." The text of the display would later state that the *Great Aerodrome* could have flown successfully in 1903 had it not been for launcher problems. In fact, it was by no means a flyable machine and lacked any means of control. It had flown, but only after being modified by Glenn Curtiss, who was involved in a heated patent infringement struggle with the Wright brothers. Orville Wright was so incensed by the Smithsonian's display of the *Great Aerodrome* that he sent the original Wright *Flyer* to the Science Museum in London. After the Smithsonian recanted, apologized, and agreed to properly display the *Flyer*, it returned home in 1948. The *Great Aerodrome* is now on loan to the Virginia Air and Space Center in Hampton.

Today, pieces of the No. 5 lie on Poppert's work table. For reference, he is using Langley's book on the Aerodrome series. "It's always interesting to see the original drawings and how they put things together," says Poppert. "It's been a pretty big help." Men stare off the page from a photograph of Langley's workshop, which doesn't look all that different from this corner of Garber. "It'd be interesting to know who Manly is in the photo," says Poppert. His admiration for the workmanship of the No. 5 is evident as he carefully explains how the small gasoline-fired boiler produced steam power, or how the intricate launching mechanism operated. As Poppert works, the book lies open on the table, and mechanical kinship grows between craftsmen old and new.

—*John Sotham*

ARTIFACTS


MARK AVINO

In 1973, Braniff International decided to publicize its South American routes by flying an airliner that looked like no other. This 1:50 scale model of a DC-8-62 shows what resulted when Braniff president Harding Lawrence asked modern artist Alexander Calder to substitute an airliner for a canvas. For a fee of $100,000, Calder worked on models for six months before his final design was transferred to the actual aircraft by Braniff's maintenance staff. Sporting the Calder paint job, the DC-8 flew passengers for seven years. Located in the Air Transportation gallery, the model was donated to the Museum by Braniff in 1976.

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700 Mon.–Sat., 9 a.m.–4 p.m.; TTY: (202) 357-1729.

April 2 Monthly Sky Lecture. Einstein Planetarium, 9:30 a.m.

April 7 G.E. Aviation Lecture. Albert Blackburn, aviation consultant and former test pilot, will talk about manned suborbital rocket launches prior to Mercury. Langley Theater, 7:30 p.m.

April 20 Exploring Space Lecture Series. Chris P. McKay of NASA's Ames Research Center will discuss Titan, Saturn's largest moon.

April 23 & 24 "Wings and Things" Open House Weekend. More than 100 aircraft and space artifacts on display. Live music, model-building, and educational demonstrations. Paul E. Garber Facility, Suitland, MD, 10 a.m.–3 p.m.


COURTESY RICHARD C. DATIN

This model of the Star Trek Enterprise *(pictured here with model makers Richard C. Datin, Mel Keys, and Volmer Jensen, left to right, in 1964) will be on display at the Garber annual open house on April 23 and 24.*

May 7 Monthly Sky Lecture. Einstein Planetarium, 9:30 a.m.

May 17 Wernher von Braun Memorial Lecture. D. Allan Bromley will explore the choices confronting the U.S. civilian space program. Langley Theater, 8 p.m.

May 18 Exploring Space Lecture Series. Bradford A. Smith, a veteran of the Mariner and Viking missions to Mars, will trace the history of imaging the planets of the outer solar system. Einstein Planetarium, 7:30 p.m.

May 26 Charles A. Lindbergh Memorial Lecture. Jean Ross Howard will speak about the Whirly Girls helicopter pilots. Langley Theater, 8 p.m.

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4 Butterfly Unit included	✓ YES No extra cost.	✗ NO Costs $200 extra.	✓ YES, **BUT...** You must assemble before each use, and disassemble to use bench press.
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6 Comfortable bench	✓ YES Padded bench is a full 47" long, 12" wide, and a comfortable 20" high.	✗ NO Padded bench is only 40½" long, making some lying down exercises awkward.	✗ NO Padded 40" bench is short, narrow (only 9" wide), and too high (24") off the ground.
7 Hydraulic cylinder resistance system	✓ YES Adjusts to your personal resistance level with a simple twist of a dial.	✗ NO Uses rubber bands which must be changed to vary resistance level.	✗ NO Uses complicated cord/pulley/mechanical resistance system.
8 Full refund of return freight if unit returned	✓ YES If not satisfied, we will refund your cost, shipping/handling charges, and all return freight!	✗ NO You pay over $85 to return. It must go by truck to Oregon!	✗ NO You pay about $65 to return by UPS.
9 Payable in installments	✓ YES 9 easy installments of just $36.56! ($49.00 S/H added to first installment.)	✓ YES, **BUT...** You pay $39 per month for the next *2 YEARS!*	✓ YES, **BUT...** At 4 payments of $250, each installment is almost as much as the total cost of a **HEALTHMAX**!

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The Search for the *Challenger*

On January 28, 1986, a cold, clear Tuesday morning, the shuttle *Challenger* sat at the Kennedy Space Center awaiting launch. As the countdown reached ignition, puffs of black smoke were photographed emanating from a joint on the right solid-fuel booster rocket. Fifty-eight seconds after liftoff, a flame leaped from that joint. Fifteen seconds later the main fuel tank exploded, blowing the orbiter to pieces. As the world watched, the cabin and its crew of seven plunged 12 miles to the Atlantic.

Immediately, Coast Guard and Navy ships were dispatched to assist the two NASA recovery ships already on site. The first priority was recovering the crew cabin, which, along with the boosters, could reveal the cause of the explosion. But in the first few days, the only things retrieved were a few floating pieces of fuselage.

Although a profusion of cameras had photographed every millisecond of the tragedy, the ships still had to search approximately 480 square miles of ocean. A 12-ship flotilla, including three miniature submarines, combed the ocean floor with the latest in sonar gear. The Navy called active reservist divers, who were rotated into the ships' crews for two-week intervals to spell the more rugged active-duty divers. As an active reservist from Mobile Diving and Salvage Unit-2, Detachment 608 in Jacksonville, Florida, I was assigned to the USS *Preserver* salvage ship. This ship's crew had been diving to investigate various sonar signals for three weeks when I reported aboard on February 24. Like millions of other Americans, I had watched in disbelief the endless replays of the *Challenger* disaster on television. With mixed feelings I listened to the briefing given by the active-duty chief. I knew there were no survivors but I wanted to do something to help out.

The daily routine, weather permitting, had each ship searching a particular area within the search grid. After receiving coordinates of all sonar contacts in that area, each ship checked out every one to visually determine if it were part of the *Challenger* wreckage. If we weren't sure, we winched the object up and took it with us. Astronauts were assigned to our ship to brief the divers on shuttle structural configuration and components, and they brought manuals with detailed pictures of the entire shuttle and its boosters. We returned to port only to unload debris, replenish food, fuel, and water supplies, or escape the recurring high seas.

PATRICIA RAINE

Bad weather in February, March, and April drastically reduced the number of dives we could make. Even the two-man subs couldn't launch when the northeasters were blowing. Other days it was too dangerous to dive at all. Rough seas and strong currents often limited our underwater vision to less than 10 feet, so we had to make extra dives just to locate an object picked up by sonar.

The amount of debris in the water was another major problem. Some thirty years of rocket testing by NASA and the military had littered the ocean floor with burned-out boosters and

twisted wreckage. The searchers had to identify and log thousands of sonar contacts. We found everything from spent first stages of Saturn rockets to shipwrecks at 75 to 1,200 feet.

We used both scuba and MK-12 deep-sea diving systems, which supply air to divers through a hose from the surface. Scuba was used mainly in depths to 120 feet and in rough seas when MK-12 hose diving wasn't possible due to the rolling and pitching of the ship, which yanks the diver around like a marionette. A submersible robot was used to recover debris in water deeper than 240 feet.

After much searching, the sonar found three major debris fields 12 to 18 miles northeast of Cape Canaveral. The *Preserver* anchored in one of these fields on a Friday in March, and its crew began making dives on contacts. Late that afternoon, after receiving a set of coordinates from another search vessel, we proceeded to a new site.

By the time the divers hit the water it was nearly dark. They descended and stayed on the ocean floor six minutes longer than they were supposed to. After surfacing they were treated in the onboard decompression chamber. They had been unable to positively identify the debris in the darkness. All diving operations ceased for the night. As we cleaned and prepared the dive gear for the next day, rumors swept through the ship that this was it: the crew's cabin. That night I stared at the pipes above my bunk for an hour in the dimly lit berthing compartment before finally falling asleep.

On Saturday, March 8, an electrician mate diver named Riker and I hit the water in scuba gear at 0700 hours. We descended 100 feet to the ocean floor and immediately saw a lot of debris. As we swam three to four feet above the bottom, we spotted, on the horizon of our limited visibility, a large dark object protruding from the sandy bottom. We swam closer and the debris field became more cluttered. Heat-resistant tiles were scattered between piles of twisted metal and spaghetti-like piping. We saw the large airlock door used to seal the shuttle crew compartment lying almost hidden in the sand like a giant stingray. As we approached the dark mass, its nose buried in the sand, I could hear my heart pounding above the exhaust of my scuba regulator. Surely this was the crew's compartment, though it barely resembled the pictures we had been shown.

Inside we found a heap of rubble. The impact had broken all the seats loose from both levels of the cabin and slammed them forward in a mass of metal

and wiring deep into what was left of the nose section.

Suddenly we came to a halt: two legs of a white spacesuit were protruding horizontally from the wreckage. It was a ghostly sight in the murky water. I reached up and grabbed the right foot to find it was only an empty extravehicular activity suit that had fallen out of a locker and inflated with water in the half-knot current. As we pressed farther into the compartment we saw, sandwiched between the seats, dark blue uniforms. Convinced that this was indeed the crew's compartment, Riker and I backed out of the narrow opening while we kept a watch for sharks. Snagged on piping was a small white bag, which I pulled out and wedged under my weight belt. After surfacing we reported our findings and gave an astronaut the bag. He identified it as a personal gear bag that could have come from only one place: the crew's compartment.

The captain repositioned the ship as close to the wreckage as possible and dropped anchor. The rest of the day was strangely quiet as we dove until nearly dark retrieving the badly decomposed remains of the *Challenger* crew. We labored into the night disinfecting the ship's fantail with Betadine and fresh water and then returned to port.

As we approached the mouth of Port Canaveral, the state park on the south shore of the inlet lit up like Wrigley Field with headlights from the RVs of scores of reporters camping there. NASA employees and ambulance attendants took all the debris and remains off the *Preserver*.

The next day my first two weeks of active duty were over, so I went home, never to be quite the same. The experiences of March 8 were burned into my memory: the underwater graveyard, strewn with debris, the battered cabin nose burrowed into the ocean floor, and the blue uniforms embedded in a mass of twisted metal.

Later that month I returned for two more weeks of duty. Because of recurring bad weather the search for more wreckage continued into April. Again, we hopscotched from one sonar contact to the next, confirming and recovering pieces of the spacecraft.

Despite all obstacles, the salvage teams recovered major portions of both boosters and the orbiter, along with the crew cabin and all flight recorders. After three months of 12- to 16-hour workdays, an order rang out over the ship's intercom: "Now hear this. All hands cease and desist the search and recovery operation for the space shuttle *Challenger*. Secure all dive stations. Prepare to get under way." The *Preserver*'s work was done.

—*Glenn Arnett*

Sandbagged

Folks in Oklahoma just aren't cut out for martyrdom. They've had their share of adversity: a drought, oil crises, floods, even an occasional loss by the Sooner football team. But in Oklahoma, it's easy to see any setback as temporary, any bust as a prelude to the next boom.

So it's not surprising that the Boise City bombing—the night that World War II came to Oklahoma—is a matter of civic pride. Last summer the town installed a plaque and statue in the town square, saluting the six sand-filled practice bombs that almost resulted in the war's first domestic casualty on High Plains soil.

On the night of July 4, 1943, the town had put its wartime worries on the shelf and celebrated with fireworks. The party ended at a fitting hour, but the real fireworks began shortly after midnight. A bomber crew on a routine training mission left Dalhart Army Base, 50 miles south of Boise City in the Texas Panhandle, aboard a B-17E. The crew's assigned navigator had fallen ill; he was replaced on the flight by a novice named John Daly.

Instead of heading for the illuminated practice range near Conlen, some 20 miles northeast of Dalhart, Daly mistakenly guided the B-17 due north. Soon the crew was over the crosshairs formed by highways intersecting at the lights of the Boise City courthouse. With no clue they were so off track, the boys let Boise City have it.

The first 100-pound sand bomb blasted open a frame garage, leaving a 20- by 40-inch crater and uncovering a stash of girlie magazines that was later traced to a preacher's son. After circling, the crew tried again, this time missing the courthouse by several blocks but sparing the First Baptist Church by only a foot. Four more strikes landed no nearer than 200 feet from the courthouse. One bomb narrowly missed a fuel truck; the owner made a judicious retreat from town seconds later.

In the midst of the blitzkrieg, Sheriff Harris "Hook" Powell, who lived with his family in an apartment atop the courthouse, dashed to the telephone company a block east. There he found another resident and two errant soldiers from Dalhart. They called the base radio operator, but it took a while for the operator's urgent Morse code message to reach the bomber cockpit. It was up to Frank Garrett, the local utility company manager, to outwit the attackers. He ran to the power plant and pulled the town's master power switch, killing all the lights. That finally sent the attackers home, apparently satisfied with their handiwork.

Norma Gene Young, who ran the town newspaper with her husband for many years, was a teenager in 1943, and she sheepishly admits to having slept through the whole affair. "The day after it happened, I never saw so much brass in my life," she recalls. "They were afraid of getting the heck sued out of them, I guess, but nobody ever said a thing about suing anybody." Indeed, not a soul had been injured, and property damage was confined to the garage the first bomb had wrecked. The worst indignity was perhaps the uncovering of the magazine stash. "The kid who had them was only about eight years old," says Young. "Years later he worked for us at the newspaper as a printer's devil [apprentice]. He was an ornery kid—good, but ornery."

The crew who bombed Boise City were given the choice of court-martial or immediate shipment to overseas combat. After accepting the latter, they picked up a new B-17 and eventually joined the 94th Bomb Group, earning a slew of medals and citations, all with the navigator who'd been ill that fateful night, Samuel Assimotos.

Fate had an even greater twist for John Daly. After being reprimanded, transferred from Dalhart, and given further navigation training, he went to Europe with the Eighth Air Force. During a raid over Brussels, a burst of flak killed the pilot and injured the copilot of Daly's B-17. The navigator took the controls and landed in England, winning his third Distinguished Flying Cross.

The people of Boise City felt sure they were the only U.S. civilians who had survived a bombing raid on their hometown. But in 1990 Young learned that Sierra Blanca, Texas, had experienced its own accidental bombing on July 13, 1944. Ten bombs fell in and near that town; no structures were hit. And last summer, just after celebrating the 50th anniversary of its beloved calamity with the installation of a cement "crater" with a bomb in it, Boise Citians heard about a farm near Dickens, Nebraska, that had been inadvertently attacked in December 1943.

Trumped in adversity—not once, but twice. But Young is philosophical: "It was fun while it lasted."

—*Robert Henson*

JAN ADKINS

HOW THE SKUNK WORKS WORKS

by William E. Burrows

Once the Air Force unveiled the F-117 stealth fighter in 1988, the hottest topic of speculation among the fraternity of aerospace and intelligence junkies became an enigmatic flier everyone calls "Aurora."

The speculators say the new unidentified flying object is diamond-shaped and hypersonic, yet able to stop on a dime and change direction. When it prowls over the southwestern United States, mostly at night, it makes the earth shudder from Santa Catalina Island to Nevada's Groom Lake military test facility. It blows perfect smoke rings at dizzying altitudes and has an engine that makes an eerie roar and can stop abruptly. It is manned—or it is a robot with a computer for a brain. Its mission is reconnaissance or designating targets with a laser or strategic bombardment or launching satellites into orbit on a single-stage rocket or all of these tasks or none of them.

If there is one thing almost everyone agrees on, however, it is that the mystery craft could have been designed and built by only one organization: the Lockheed Advanced Development Company, better known as the Skunk Works. Ben R. Rich, the former head of the company and now a consultant to it, says that beginning in 1991, when evidence of the mysterious flying machine began to accumulate, he received an average of five calls a week—perhaps a hundred altogether—from people trying to pry the secret of the phantom vehicle out of him. He told them that his security clearance prevented him from discussing the matter.

Rich feels no such constraints when talking about the Skunk Works. Over lunch at a restaurant, he describes the company's spirit and operating procedures with the animation of a religious zealot. Aviation's gray-haired *enfant terrible* gets so excited, in fact, that he has a coughing fit that leaves him red-faced and gasping for air. He wears a watch decorated with the religion's icon: a skunk. The dogma, deceptively simple, is this: make things "black and skunky" (secretly, efficiently, and innovatively).

If skunkiness is a techno-religion, then Clarence L. Johnson, who died in 1990 at the age of 80, is its patron saint. Johnson—or simply Kelly—founded the Skunk Works at Burbank Airport in 1943 with the development of the XP-80 Shooting Star, the prototype for the country's first operational jet. He had previously designed the P-38 Lightning and would go on to play a leading role in the design of a series of world-class military and civilian aircraft, most notably the F-104 Starfighter and the U-2 and SR-71 spyplanes. Rich says that the "SR," which Johnson started designing with a slide rule on April 17, 1958, could potentially reach 90,000 feet and a speed of Mach 3.5. Others believe it was substan-

"Be quick, be quiet, be on time." That's the simple creed of the company that has created some of the world's most exciting aircraft, from the XP-80 to the F-117A.

Clarence Johnson, better known as Kelly, founded the Skunk Works to design the prototype for the P-80, America's first operational jet.

tially faster than that. Now retired from the Air Force (it still flies for NASA), the SR-71 holds a spate of speed records, including a flight from Los Angeles to Washington, D.C., in 64 minutes, 2 seconds, or 2,144.8 mph (see "The Blackbird's Wake," October/November 1990).

Although the Skunk Works celebrated its 50th anniversary last year, it was more a team within Lockheed rather than a corporate entity until Lockheed officially dubbed it Advanced Development Projects a few years after its formation (it became the Advanced Development Company in 1990). The nickname came from the "Skonk Works" in Al Capp's Li'l Abner comic strip, though precisely how it happened has been lost in the mists of time. One version says an engineer named Irv Culver, who worked with Johnson on the Shooting Star inside the supersecret Burbank plant, likened its isolation to the comic strip's hidden still, which manufactured Kickapoo Joy Juice, a moonshine made from old shoes, skunks, and other evil-smelling ingredients. Rich says that Culver invented the name because of the stench from a plastics factory across the street. In the 1960s Capp objected to the appropriation of "Skonk," so it was changed to "Skunk."

"By that time," Rich adds, "we were so successful and the term 'Skunk Works' was so identified with our success that many companies and people, including President Lyndon Johnson, used it generically to connote well-managed programs." Today the term is idiomatic throughout the aerospace industry for a small, tightly run, efficient operation. Lockheed registered it in 1973, along with the company's symbol: a drawing of a little skunk whose forelegs are folded in evident satisfaction.

If the Skunk Works had to come up with a new company symbol, it would probably be a cloudy crystal ball. According to Wolfgang Demisch, who studies the aerospace in-

ROSS HARRISON KOTY

dustry for BT Securities Corporation, "The individual companies within the industry have been manic-depressive throughout the post-war period, expanding and contracting with each program cycle, but the overall industry was typically a little bit more stable. What's happening now is the programs are contracting and successors are not in sight, at least that I can tell. So there is a brutal job of downsizing, which I think is inevitable."

Yet Lockheed officials talk optimistically about the future. Dennis E. Thompson, the Skunk Works' vice president for business management, maintains that the company has always had profits "on the high side of average." Daniel M. Tellep, the Lockheed Corporation's chairman and chief executive officer, is more specific. He claims that the Skunk Works grossed roughly $700 million in 1992, making it one of Lockheed's most profitable subsidiaries. The company says the 1993 figures are comparable.

Nonetheless, as the cold war thawed and uncertain times approached in the late 1980s, it became clear that the company was going to have to move from Burbank to Palmdale, 35 miles southwest of Edwards Air Force Base in California's high desert. Palmdale offered more usable space, better security, less congestion, cheaper land, and fewer expensive environmental regulations. In 1987 the Skunk Works and the entity it once reported to, Lockheed California (no longer in existence), occupied 10.3 million square feet of plant space in four locations. By this June, all 4,500 of the company's employees will have been relocated to Palmdale. By 1995 they will be working in only 3.1 million square feet of space.

The organization still observes the 14 basic operating principles Johnson laid down long ago. They do not read like supercilious corporate dicta churned out by MBAs who are still teething on Management 101. Instead, Kelly's creed is reduced to a simple homily spun by a quintessential engineer, probably with a pencil stub, who was also trying to make a buck.

The rules come down to keeping the operation small, secret, adaptable, tightly run, and in close communication with its customers. The manager of the Skunk Works has near-total authority. It falls to the customer—mainly the U.S. gov-

The U-2R, a later version of the famous spyplane, carries a radar system in its nose. Early U-2s flew so high they were invulnerable to attack: then in 1960 Soviet missiles downed one flown by CIA pilot Francis Gary Powers, causing an international incident.

A series of carrier trials demonstrated that the U-2 could be based at sea, but the concept never advanced beyond the testing stage.

Ben Rich, pictured here in the cockpit of an F-117, became the first president of the Lockheed Advanced Development Company in 1990.

The fabrication of titanium parts presented the Skunk Works with a major technical challenge during the SR-71 program (below). In the air, the Blackbirds were thirsty craft (opposite), gulping down 8,000 gallons of fuel an hour when cruising at Mach 3. The world's fastest air-breathing aircraft, the SR-71 was retired by the Air Force in 1990 but continues to fly scientific missions for NASA.

ernment—to give the contractor considerable leeway in developing hardware. The number of people involved in a project must be restricted "in an almost vicious manner," Rule 3 stipulates with disarming frankness, while number 6 calls for monthly cost reviews and projections that will not "surprise the customer with sudden overruns." Rule 9 insists that Lockheed have the authority to test the airplanes it produces in order to maintain its overall competence; 11 states bluntly that the customer is expected to pay up on time "so that the contractor doesn't have to keep running to the bank to support government projects." The last rule says that employees ought to be paid according to their performance, not according to the "number of personnel supervised."

Johnson was considered tough—Irv Culver claimed to have been fired "about twice a day" by him, and others called him "beady-eyed." He belonged to a breed of aeronautical engineers who were highly creative, often salty characters, the kind who wrote the books rather than hid behind them. Harrison Storms, Johnson's counterpart over at North American Aviation, was said to "think like air," and so could Johnson, Ben Rich, Douglas' Ed Heinemann, Supermarine's R. J. Mitchell, Theodore von Kármán, Jack Northrop, and a handful of others. Instinctive aerodynamicists, they could feel whether a design was right long before they picked up their slide rules. "I'll make the Statue of Liberty fly if I have to," boasts Rich. Bright, imaginative engineers find that working for such men is fun, and they tend to become intensely loyal disciples who are driven to please their leaders. Rich quotes Johnson all the time; others quote Rich. For such designers, the worst nightmare is not the failure of a project—the Skunk Works has had at least three—but becoming so stuck in a bureaucratic quagmire that projects cannot even start. When Rich thinks about the Pentagon he sees Lilliput.

He misses the days when Lockheed got what amounted to a blank check from the CIA's Richard M. Bissell Jr. to develop the U-2 and its successor, the SR-71. With a free hand and little oversight from the spy agency, the Skunk Workers had the U-2 flying in August 1955, nine months after the contract's signing; the SR-71 took to the air in 27 months. (The Skunk Works is quick to point out that McDonnell Douglas' F-15 took 30 months and its Phantom II 43 months; Convair's B-58 took 52 months, as did North American Rockwell's B-1.)

Bissell enjoyed working with Johnson and his imaginative engineers and deeply respected their ability to create amazing spyplanes quickly. But the Air Force, Rich complains, tends to infest its contractors with hordes of technical representatives who make suggestions, issue nettlesome orders, and push endless rules. After only three years, they get reassigned. "They therefore do not have to live with their mistakes," Rich grouses.

"Why must the SR-71 meet the Arizona Road Test requirement?" he asks, as he often does, referring to the amount of dust the high-flying airplane's engines had to be able to ingest and still keep working. "Why must we paint Air Force stars and bars on the SR-71," as the Air Force ordered? "I said, 'You dumb [expletive], you know how hot that airplane is [at Mach 3 and above]? It's 600 degrees. You know what 600 degrees is? It's the temperature under your broiler.' I said, 'Take a piece of metal, paint it, and stick it under your broiler.' "

As proof that the CIA is more efficient to work with than

Before becoming Skunk Works president in 1990, Sherman Mullin (here with an early model of the YF-22) was F-117 program manager. Unveiled in 1988, the stealth fighter (above, from the cockpit; and top) had been a long-rumored top-secret program. Before it went public, the F-117 was kept under tight security (right).

the Department of Defense, Rich and others often cite the fact that their company returned over $2 million of the $20 million the agency gave it to develop the U-2. This, they say, shows that they are more efficient when left almost entirely on their own and don't become mired in the Pentagon's rules and regulations.

So how did the Skunk Works also manage to bring in the F-117A Nighthawk—an Air Force program—under its projected cost? According to Lockheed's Dennis E. Thompson, the F-117A's performance was such a "quantum improvement" over what had been expected that there was a cost underrun: $30 million, says Rich. Thompson credits the Air Force with helping to realize the savings. "We didn't do this all ourselves. It was their support, their assistance, their direction that helped achieve it," he says, adding that Lockheed made "an unacceptable level of profit" as a result and returned the excess by not billing the government for a number of changes it requested.

Michael Harris headed the 4450th Tactical Group, which ran the F-117A program in absolute secrecy under the guise of testing A-7 avionics. He does not dispute the notion that a bloated bureaucracy impedes progress. But, he is quick to add, part of the reason for the F-117A's success is that the Air Force contingent working with Lockheed to develop the plane operated like the Skunk Works itself: it was small, tightly integrated, and in close contact with Lockheed's engineers. Every six weeks the project had a Program Management Review, in which the engineers and the airmen—down to non-commissioned officers, according to Harris—met to iron out problems.

"Ben never forgot the Golden Rule," Harris says: " 'He who has the gold makes the rule.' If they did something I thought was stupid, they'd reverse it. If we had a problem with a piece of equipment or a system, they'd jump through their rear end to get it fixed. When it came to the crunch, the Air Force won them all." But, Harris says, "It was like a man-and-wife relationship where control was concerned. It didn't matter who was in charge; what mattered was just getting the job done right."

In keeping with its no-nonsense philosophy, Johnson insisted that reports and memoranda be kept short and to the point. "Don't put all that crap in a report because it's just paper pollution," Rich recalls Johnson declaring. Whatever the aeronautical capabilities of Northrop's B-2 stealth bomber, Rich has marked it as a paper polluter and a devourer of manhours *extraordinaire*. This may account for why it took more than five years to get the stealth bomber into the air. Rich says an Air Force general told him that at one point in the program, "they were turning out 33 million sheets of paper a month. That's a million sheets of paper a day. I'd like to have the tree concession. No wonder the damned airplane costs $1 billion!"

And whereas 240 Lockheed and Air Force people worked on five F-117As during the peak of its test program, 1,200

Its odd angles, designed to give it a low radar profile, and swallow tail make the F-117 one of the strangest-looking craft flying. Before beginning production, the Skunk Works first constructed a full-scale wooden version (opposite).

people were involved in flight testing the first B-2, and 700 more had joined the effort by the time the second rolled out, according to Rich. "Tell me what 1,900 people do testing two airplanes," he asks.

Loye W. Miller of Northrop public affairs counters that comparing the F-117 and B-2 programs is like comparing "an apple to a watermelon." Furthermore, he says, "well into the mainstream of the development process, the Air Force completely restated the mission of the plane, *adding for the first time* the requirement that the B-2 operate at low as well as high altitudes. This necessitated a complete redesign of the wing, a change which added years to the early stages of the program." Perhaps Kelly Johnson would have cited the Skunk Works' Rule 10: "The specifications applying to hardware must be agreed to in *advance* of contracting."

According to Rich and others, the Skunk Works' relatively small size not only contributes to its successes but also minimizes its failures. The company has had several of the latter. One was a small commuter airliner named Saturn; two prototypes were constructed in the mid-1940s, but the aircraft was knocked out of the running by a glut of war surplus aircraft. Another was the Navy XFV-1 vertical-takeoff turboprop research plane of the mid-1950s, which was severely underpowered. A third was the CL-400 Suntan—a planned liquid hydrogen-fueled reconnaissance plane that was canceled in 1959 because of range deficiency and problems with ground transport of the fuel. They caused relatively little financial damage, in Rich's view, because they represented relatively small corporate commitments.

The Skunk Works' small physical size has its own advantages. The drawings have always been produced within a thousand feet of the shop where the prototype is built, Rich says, so engineers and shop personnel can quickly iron out discrepancies. When a drawing is complete, the engineer goes into the shop and shows it to the people responsible for "bending metal." If they can't follow the design, the problem is red-penciled, new drawings are issued, and the old ones are destroyed.

All of the black programs have necessarily involved exceptionally tight security. And in at least two of them, one involving the Air Force, the drawings themselves led to embarrassing security problems.

"Kelly believed in the perimeter type of security. We had a guard and one entrance and everything that came in stayed in," Rich says of the Burbank facility. "We were like a sponge. Once it came in, if you wanted to get rid of anything, you either cut it up—shredded it—or burned it. We didn't stamp any of our documents. Not one U-2 document, not one SR document, was stamped. This way, if anybody found it, nobody wanted to read it. Everybody wants to read secrets. So we stamped nothing, and nobody would know what was secret and what was not secret."

In the 1970s, Rich adds with disgust, the Pentagon changed the rules, requiring that classified documents be stamped top and bottom. "We then had to go through all of our programs and classify everything. I think we had to do something like 90,000 documents on the U-2 program, and the airplane was over 20 years old. It was stupid." He points out that by then the Russians and the Chinese had shot down at least five U-2s and therefore owned their carcasses. But that made no difference to the Pentagonians, Rich recalls; every last piece of paper still had to be hand stamped.

Kelly had his own rules on classified paper. One held that if a document wasn't needed, it should be destroyed. This caused yet another flap when incredulous Air Force security officers showed up at Burbank in the mid-1980s to conduct an audit of classified documents, only to learn that the Skunk Workers couldn't produce them. "They found we didn't keep records," Rich recalls. "They asked us, 'Where are the records of things you've destroyed? Where are your witnesses?' We didn't have all of that. So they said, 'Well, if you don't have a record, then you've lost it.' I said, 'Bullshit, we just got rid of it. We didn't lose anything.' " Rich had to admit that security within the perimeter was lax, however, so he and his engineers were soon doing their own desk-by-desk audit and putting the results on a computer.

The laxity allowed at least one classified document to make an unauthorized trip off the premises. It was a full drawing of the F-117A, which a married shop worker brought to his paramour to impress her. The lady was so impressed she called Lockheed, which fired the hapless Romeo rather than prosecute him for breaching security. A trial might have exposed the then-secret project to embarrassing publicity.

The F-117 also provided a career low point for Sherman Mullin. He had been manager of the F-117 program for only a month when, on April 20, 1982, the first production F-117 crashed on its maiden flight, seriously injuring the pilot. It turned out that the airplane's roll-rate and pitch-rate gyroscopes had been, in effect, crossed when they were installed, causing the plane to roll 90 degrees to the left instead of climb as it took off. Mullin was faced with a harrowing internal audit, which turned up some 100 deficiencies. One key problem obviously had to do with the way instruments were installed and tested before flight.

Mullin's career survived that setback, as did the F-117, which proved its worth during the Persian Gulf war. In December 1990 Mullin was appointed president of the Skunk Works, a position he held until he retired in February. Jack E. Gordon, Mullin's successor, takes over at a time when belt tightening and diversification will be crucial. "I think that the Skunk Works at this point needs superior leadership more than perhaps any time in the last 40 years," says BT Securities' Wolfgang Demisch, "because whoever is in charge is going to have to make some very, very painful decisions in terms of what to kill and what to fund."

One challenge the company faces is due, in part, to its success. "Success means you start to produce a reasonable number of airplanes," Demisch says. "You get into building more than onesies or twosies, but building dozens." And then the concern shifts to keeping the production team up and running. "In some respect, building a bunch of F-117s put them into the same problems that all aerospace companies continually face," says Demisch, "namely, what do we do when this program runs out?"

"That is a concern," says Jack Gordon, "and that's why we think in terms of low-rate production and limited quantities. In truth, the limited production goes a long ways to providing the resources that allow us to proceed with all the novel concepts that we do. You have to have some sort of funds." Gordon, who joined the Skunk Works in 1964, has worked on the SR-71, TR-1, and F-117 programs.

The Skunk Works is also trying to sell variations of the F-117. "Part of the defense environment today is that we're not going to have new starts, we're going to have to do derivatives and small production runs," says Gordon. "We think the F-117 program lends itself to that." The company hopes to sell a specially reinforced carrier-based version of the F-117A to the Navy—the AF-117X. The aircraft was once known as the F-117N Seahawk but the name was changed when Sikorsky, builder of the Seahawk helicopter, objected. The new designation underscores Lockheed's vision of the AF-117X as the replacement for the AFX, a program to develop

a new Navy fighter that was cancelled in September. The Navy, however, has not been enthusiastic about the AF-117X: it sees the plane's capability as too limited and its adaptation to carriers too expensive—as much as $100 million per aircraft. Ironically, one of the competitors is an aircraft the Skunk Works helped create: the F-22, produced by Lockheed's Aeronautical Systems Company.

The Skunk Works is also competing with McDonnell Douglas to build the Advanced Short Takeoff/Vertical Landing aircraft, a supersonic follow-on to the Harrier. Thirty percent of the work on the program would be done in the United Kingdom, so if the Skunk Works wins the contract, it would mark the first time it has worked with a foreign country.

The company is also turning increasing attention to the heavens. "We are looking very hard at access to space," says Gordon. The company wants to build a single-stage-to-orbit winged launch vehicle that would take off like a rocket and land like an airplane. Called the Aeroballistic Rocket, the craft would be smaller and simpler to operate than the shuttle and carry all of its fuel internally. "We're absolutely convinced that incremental changes to Delta and Titan and shuttle aren't going to make us competitive," says Gordon of U.S. launch capability. "We've lost 70 percent of the commercial launch market now to foreign competition, and trying to do what they do without massive government support would be inappropriate."

An air-breathing hypersonic plane, possibly capable of reaching Mach 26, is also on the drawing boards. While the projected weight of the National Aerospace Plane, which was virtually killed last year by the Air Force and NASA, was 550,000 pounds, the Skunk Works version would weigh a relatively modest 80,000 pounds, or about 10,000 pounds more than an empty SR-71. The company has also designed stealthy reconnaissance and military communication satellites that cannot be tracked and attacked. Helping to protect such spacecraft is a top priority of the Air Force's Space Command, so no one will touch that subject in public.

One of the Skunk Works' more unusual designs is a stealthy ship called the Sea Shadow, a 160-foot-long, twin-hull vessel that looks like a cross between an F-117A, the Civil War ironclad *Merrimac*, and Darth Vader's helmet. Intended for the Navy, it was constructed by the Lockheed Missiles & Space

Company and unveiled last April after a decade in development and testing at a cost of $195 million. Such a ship would be ideal for launching surface-to-air missiles to protect carriers or for landing commando teams at night.

But the Sea Shadow was not the Skunk Works' first venture onto the high seas. It had previously designed a robotic grappling claw for the *Glomar Explorer*, a mining ship supposedly belonging to reclusive billionaire Howard Hughes. In reality, the vessel was owned by the CIA and had one of the most imaginative and audacious missions of the cold war: the recovery of a Soviet diesel submarine that exploded and sank 750 miles northwest of Hawaii in 1968. Although the operation was reported by the news media in 1975, the results of the top-secret project remained a mystery until last June, when Russian scientists acknowledged for the first time that the *Glomar Explorer*'s huge robotic claw did manage to grab and raise the sub's bow section, which contained two nuclear torpedoes.

Reportedly, the Skunk Works is also forming alliances with U.S. weapons labs such as the Lawrence Livermore and Los Alamos national laboratories to create Buck Rogers weapons. LADC and Los Alamos are apparently trying to use narrow, potent beams of microwave pulses to disable the engines and computers of vehicles such as tanks and airplanes.

What the Skunk Works is not doing, according to company officials, is participating in an Aurora program. "If there is one, I sure as hell don't know about it," Sherman Mullin said last year before his retirement, adding that he didn't think the "beast" existed. "There is no engine that I am aware of that will take a plane to Mach 4, 5, 6, 7, 8, 9, or 10." One of his colleagues goes even further, stating emphatically that the UFO is a figment of the imagination. In 1992 then-Air Force Secretary Donald Rice said the same thing in a rare, almost unnoticed remark: His service had no involvement in such a program.

For his part, Ben Rich waxes nostalgic about the old days and looks ahead ruefully. During Johnson's time, he says, a lot of very bright and imaginative engineers worked at the Skunk Works: well-rounded types who communicated with each other all the time and who were so smart and knowledgeable that they didn't even have to work late. "You started at 7 a.m., when Kelly had the door locked, and went home at 4 p.m.," he recalls. Everybody had to take a vacation. "Kelly hated workaholics. He said, 'You don't make up in time what you don't have in brains.' "

But that was the golden era. It's different now. The "kids" just aren't what they used to be, and prospects in the industry are grim, says Rich. Even worse, the engineers all come out of the same mold. Skunkiness may therefore be losing its distinctive—well, aroma.

"None of the kids take the descriptive geometry course; they do everything by computer," Rich grumbles, "so all the airplanes in the future are going to look alike because they're all going to use the same database. I don't want a database. I want an *information* base. No two airplanes in the Skunk Works look alike because they have different missions. You look at airplanes that they do on computers today—the DC-10 looks like the L-1011—you can lay 'em on top of each other. That's bad. We lose creativity."

Ben Rich is getting red-faced again and his voice is rising. He denounces telephones (intrusive), copying machines (paper pollution), viewgraphs ("meeting" engineers want to make too many presentations), and the computer (a crutch instead of a tool). Not even the digital watch escapes his wrath. "Because of them," he mutters, "nobody knows what 'clockwise' is anymore."

With stealth technology developed by the Skunk Works, Lockheed built the Sea Shadow, a stealthy ship. It was unveiled last April.

Jack Gordon, who became Skunk Works president in March, will oversee the company as it moves into a future made uncertain by decreasing military budgets.

Members Only

Byron K. Lichtenberg, first payload specialist to fly aboard the space shuttle

I'll never forget the day in 1978 when Rick Chappell, the mission scientist on Spacelab-1, called to tell me I'd been selected as one of two payload specialists to train for the first mission of the shuttle's manned, reusable laboratory.

I knew I'd just been given a rare privilege. But after two flights in space, I fear the privilege is becoming even rarer. Spaceflight has gotten increasingly restrictive, a trend that may ultimately find a victim not just in the corps of would-be space travelers, but in science itself.

To avoid this fate, I believe that NASA must continue flying the non-NASA scientists known as payload specialists and keep the commitment to science alive on the space station. To understand why, it's important to know a little of the history of the U.S. manned space program and its relationship to the scientific community.

During the Apollo and Skylab missions in the 1960s and early 1970s, most astronauts were pilots who were trained to do experiments in space. The Earthbound scientists responsible for these experiments—the principal investigators—had limited contact with the crews during training and generally no contact with them during the flight.

The trend toward reduced scientific representation in space appears to be growing.

When NASA proposed the space shuttle and space station, it sought the science community's support. Because the shuttle was to offer an easier ride into orbit—a maximum of 3 Gs versus 8 or 9 Gs on previous rockets—it would now be possible to send people other than specially trained test pilots into space. NASA and the science community agreed that this should include scientists, selected and trained by the principal investigators to conduct experiments on Spacelab missions. Some of these payload specialists *are* principal investigators, others are staff researchers or co-investigators, but they are not NASA career astronauts and generally not NASA employees. Rather, they are employed by subcontractors or the institutions that are flying the experiments.

In the early 1980s NASA broadened the concept of the payload specialist to include representatives of other countries and institutions that were launching satellites from the shuttle. It also created a program called Space Flight Participant to include people such as legislators, teachers, and journalists. The SFP program was in full swing when the shuttle *Challenger* exploded in 1986.

After the *Challenger* accident, NASA reviewed its entire shuttle operation. It made the payload specialist program more restrictive and put the SFP program on hold. Three issues emerged from this review. First, NASA was concerned that people were flying without a realistic understanding of the risks involved. Second, the astronaut corps—which consists of pilots and mission specialists—was concerned about losing seats to people outside the astronaut office. (On each mission, two pilots fly the orbiter and three to five mission specialists have duties such as flight engineer, remote arm operator, and Spacelab system operator.) Third, NASA wanted more control over the selection of who flew on the shuttle.

The issue of who has the "right stuff" is a red herring. People know that flying in space is still not routine, and they should be able to take the risks if they so desire. As for the notion that astronauts are losing seats, of the 44 seats occupied on the shuttle in an average year, only four—about nine percent—are used by payload specialists. In fact, since there are seven seats available on each shuttle, payload specialists actually occupy only about seven percent. This is hardly a significant loss.

I believe the concern about control over selection is the real crux of the matter. With the SFP program effectively canceled, the payload specialist selection process was changed to include a new committee of top NASA managers that would rule on the request for payload specialists on each Spacelab flight. In the current system, if a mission specialist has the appropriate qualifications, he or she will be assigned in lieu of a payload specialist. This has been happening more and more often. For example, Spacelab-J (mission STS-47), Space Life Sciences-2 (STS-58), and International

Is an increasing exclusiveness at NASA putting science in space at risk?

Microgravity Laboratory-2 (STS-65) all had their payload specialist quota of two per flight reduced to one.

But, you may ask, if mission specialists—some of whom are highly skilled scientists—are qualified by education and training, why shouldn't they be assigned in lieu of payload specialists? I believe the reasons revolve around accountability; crew roles, responsibilities, and availability; and the support of the scientific community.

The key issue is accountability. Mission specialists are appointed to flights by the chief of the astronaut office and the head of the Flight Crew Operations Directorate at Johnson Space Center in Houston. Because they report to these people and receive flight assignments from them, their first loyalty is to NASA. Payload specialists, on the other hand, are selected by the scientists and thus are much more likely to represent the scientific point of view when it's time to make tradeoffs in mission design involving launch windows, contingency experiment operations, and so on.

Furthermore, while the payload specialists' primary responsibility is the operation of the experiments, the mission specialists have other duties. Not only do the mission specialists start science training later than the payload specialists, they also have less time for it. For example, on my second flight, ATLAS-1 (STS-45), our mission specialists were assigned 18 months prior to our scheduled launch date. But because the payload commander, mission specialist Kathy Sullivan, was about to fly the mission to deploy the Hubble Space Telescope, she was not available for our training sessions until her intervening mission was completed. Fortunately, a one-year slip of our launch date allowed her to get up to speed.

Having someone aboard from the science community can significantly enhance an experiment. Starting with the first Spacelab flight (STS-9, my first flight), payload specialists have made major in-flight changes to experiment operations. For example, we modified a group of fluid physics experiments because it was impossible to predict before the flight how fluids would behave in weightlessness. In another experiment a flash on a camera used for data collection failed, but I was able to save the experiment by improvising with a video camera and lenses. Without years of training and close interaction with the scientific teams, these modifications probably wouldn't have been made and vital scientific data would have been lost.

During Spacelab-3 (STS-51B), payload specialist Taylor Wang, the principal investigator of an experiment designed to demonstrate containerless processing in space, had to rewire his experiment to recover from a power supply failure. On ASTRO-1 (STS-35), when both Spacelab computer interface units failed, the payload specialists were critical to the successful completion of the scientific mission. On the first mission of the U.S. Microgravity Laboratory (STS-50), payload specialist Larry DeLucas—a protein crystal grower—produced far more data on the conditions necessary for protein crystallization than all previous missions had.

Having someone aboard from the science community can significantly enhance an experiment.

I feel strongly that the presence of payload specialists has greatly contributed to the success of the Spacelab program. Nonetheless, the trend toward reduced scientific representation in space appears to be growing. Initial plans for the space station called for a crew of eight, which was to include payload scientists, a position similar to payload specialist. Restructuring has reduced the crew to four to six members, *none* of whom are to be payload scientists. Yet the primary areas of science that will be investigated on the space station—microgravity and life sciences—require both the operators and the subjects to have knowledgeable, hands-on scientific interaction with the experiments.

Finally, the scientific community's support is essential to NASA's future scientific endeavors. Spacelab scientific investigators have been extremely pleased with the payload specialists' efforts, and would like to see this concept applied to the space station. To curtail this program just as we move into a greater opportunity for science in space would be folly.

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Chevy Camaro

A Hole in the Stars

For the Apollo 8 astronauts, getting to the moon wasn't half the fun—at times it was no fun at all.

by Andrew Chaikin

Excerpted from the book *A Man on the Moon: The Voyages of the Apollo Astronauts,* to be published in June 1994 by Viking.

On its launch pad at Kennedy Space Center, the Saturn V rocket is poised to send the Apollo 8 crew on a quarter-million-mile trip to the moon.

A hundred and fifteen miles up, circling Earth at more than 17,400 mph, Apollo 8 moved in that exquisite balance between gravity and momentum called orbit. Had they done nothing, astronauts Frank Borman, Jim Lovell, and Bill Anders would have remained there for days, slowed only by friction with the scant upper atmosphere. The bold difference in this flight, launched on December 21, 1968, would come late in their second orbit. At that time they would ignite the Saturn V's third-stage engine for a little over five minutes and tip the balance between gravity and momentum just enough for Apollo 8 to leave orbit and reach the moon's gravitational sphere of influence. The Translunar Injection—TLI—was scheduled to take place just two and a half hours from now. But it would happen, Borman knew, only if Apollo 8 passed its systems checks.

"I don't want to see you looking out the window!" Borman barked. They had a timeline to stick to—Anders knew that as well as his commander. But to be in orbit for the first time and not look outside! That was easy for Borman to say. He and Lovell had been here before. Once or twice, when Borman wasn't watching, Anders stole glimpses of Earth, a magnificent panorama of color and bright clarity that filled his window. Brilliant white plumes and swirls of cloud crisscrossed land and ocean. Entire continents swept past in minutes. Somewhere over the midnight Earth—was it New Zealand?—lightning glowed in the clouds far below like flashbulbs going off under wads of cotton. Anders wanted to linger here, taking in the ever-changing beauty of his home. He wished they weren't going to the moon—not yet.

But the time flew by. There was a small mishap when Lovell, under one of the couches to adjust a valve, accidentally inflated the life vest attached to his spacesuit; he would always remember the look of irritation on Borman's face. But aside from that, everything went like clockwork. What so many had doubted, including Borman, was actually happening: Apollo 8 was checking out perfectly.

At last came the word the three astronauts had been waiting for, and ironically, it came from the man originally slated for Apollo 8's center seat, Mike Collins. One of the most momentous directives ever given, it was spoken with remarkable calm and in the coded language of spaceflight: "Apollo 8, you are go for TLI."

With ten seconds to go until ignition, the computer gave a coded message to the astronauts, a flashing number 99. Translated, it said, "Are you sure you want to do this?" Lovell answered by pushing the button marked "PROCEED." Moments later, at Mission Elapsed Time 2 hours, 47 minutes, 37 seconds, the third-stage rocket came to life with a long, gentle push. The ride really did

PHOTOGRAPHS COURTESY NASA

feel like the simulator; the men sank into their couches with barely more than the force of normal gravity.

Immediately, they sensed the rocket veering to one side as it headed out of Earth orbit and onto a course for the moon. Trajectory specialists in Houston hawkeyed the moonship's path and sent word via Mike Collins: "You're looking good here, right down the old center line." Borman kept his eye on the attitude indicator, ready to take over steering if the booster's automatic system faded. Anders monitored the pressures and temperatures in the fuel tanks. And Lovell called out their ever-increasing speed from the computer readout. The numbers galloped upward: 30,000 feet per second...33,000...finally 35,532 feet per second, some 24,226 mph, the speed necessary to reach the moon. At that instant, five minutes and 18 seconds after ignition, the computer shut down the engine.

Apollo 8 was on its way to the moon.

From mission control Collins had good news for the moon voyagers: "We have a whole room full of people that say you look good." One of those people was Chris Kraft, chief of flight operations in Houston. Kraft rarely came on the radio during a mission, so Borman was surprised to hear his exultant sendoff: "You're on your way! You're really on your way now!"

Still, inside the command module there was nothing to convey to the senses this extraordinary departure, no sensation of speed whatsoever, just numbers on the computer. That changed dramatically when Borman cut loose from the spent third-stage booster, pulled away with a burst from the service module's small maneuvering thrusters, and spun Apollo 8 around. At first, it was the sight of the third stage itself—a hulking cylinder aglow in the unfiltered sunlight of space—that caught their attention. But then, as the spacecraft turned, Borman's crew could see the place they had left behind, not a landscape but *a planet,* a luminous sphere whose roundness was apparent to the eye. Apollo 8 was departing at such fantastic speed that the men could see their world receding from them almost as they watched. Already the entire globe fit neatly within the round window of the command module's side hatch.

But Borman, for one, had no time to look at Earth; he was more concerned about the cast-off third stage. As the flight plan called for, he had pulled up within a few dozen yards of the booster to demonstrate the maneuvers future crews would use to extract a lunar module from its berth. But Borman, anxious to save fuel and avoid any maneuvers that would affect their trajectory, did not want to prolong the exercise. Furthermore, he knew the booster was scheduled to blow off its excess fuel sometime soon, and when that happened it would be better not to be anywhere nearby. After conferring with mission control, Borman pulsed the hand controller and fired the maneuvering thrusters to pull away.

But the third stage seemed to be following them. Already it was spewing fans of brilliant ice particles into space, reminding Borman of a huge lawn sprinkler. For the better part of an hour Borman anxiously queried Houston on how to get away without disturbing the planned trajectory. Lovell's attempts to realign the command module's navigation platform were to no avail; the sky was full of "false stars" from the booster, and it was impossible to find any real ones to use for alignment. And right now the best landmark in this dark, sunlit ocean—Earth—was out of view. When Collins outlined a small evasive maneuver, Borman replied, "Okay, as soon as we find the Earth, we'll do it." In mission control Borman's words triggered brief, amazed laughter.

Finally, after more than an hour, Anders saw Earth drift into his right-hand window, and after more deliberations with Houston, Borman fired the maneuvering thrusters once more. Slowly, the third stage dwindled until it was just a bright star. Apollo 8 was alone in the translunar void.

"Would you pass me the flight plan, Bill?" asked Lovell.

Anders reached for the three-ring book floating in the air next to him. He gave the book a gentle push and it drifted across the cabin into Lovell's open hand. Apollo 8 was coasting moonward like a baseball fleeing the strike of the bat, and everything inside it—includ-

Rookie Bill Anders and spaceflight veterans Jim Lovell and Frank Borman (left to right) made up the Apollo 8 crew. Lovell designed the mission patch (left).

ing the three astronauts—was weightless. There was a moment back in Earth orbit when Anders had unbuckled his harness and his body hung in midair, suspended above his couch. He'd heard other astronauts talk about zero-G, but there was no way to anticipate it. No simulation could have prepared him.

In the first few hours of the mission he'd had no time to enjoy this strange new world. But sometime after TLI, well on the way to the moon, Anders climbed out of his spacesuit and found a freedom unlike any he had ever experienced. Wearing only a pair of Beta-cloth coveralls over his long johns, he floated unencumbered. With a push against his couch he propelled himself slowly past the instrument panel into the open area they called the lower equipment bay, which housed storage lockers and Lovell's navigation telescopes. There he found enough room to stretch out, or to hang inverted, his feet up by the top hatch and his head pointing at the floor. "Up" and "down" were wherever he wanted them to be. It was as if the command module had suddenly doubled in size. And in zero-G it became a wonderland; water formed perfect shimmering, dancing spheres. Cameras twirled and tumbled at the touch of a fingertip or lingered in midair when not in use.

There wasn't room for gymnastics, but Anders had enough space to tuck himself into a ball and, with a nudge against the wall, start tumbling, like an acrobat magically suspended at the top of his arc. It would have been great fun if it weren't for one thing: suddenly, Anders was overcome by nausea.

For years NASA doctors had worried about motion sickness in space, fearing that zero-G would confuse the inner ear, which gives the body its sense of up and down. But no astronaut had ever returned from orbit with anything but glowing enthusiasm for weightlessness. Borman and Lovell, for example, had spent two weeks in free-fall with no ill effects. But the Apollo 8 command module had something that the phone booth-sized Gemini didn't—room to move. The doctors feared that simply by floating around, an astronaut would push his vestibular system over the edge.

Still, Wally Schirra's crew returned from Apollo 7 with no complaints. Maybe it came down to the individual, with no way to know who would be sick and who wouldn't. The only thing Anders knew was that he needed to be still for a while. Soon he felt better. Several hours later, Anders not only wasn't sick, he was so comfortable that it was as if he had always been weightless.

But one aspect of weightlessness was so unpleasant that even the thrill of exploration didn't make up for it. If this marvel of engineering called Apollo had one major design flaw, it was the "Waste Management System." For urine collection there was a condom-like fitting attached to a valved hose that led to a vent on the side of the spacecraft. On paper, at least, it seemed like a reasonable if low-tech way to handle urinating in zero-G, assuming you got over your anxiety about connecting your private parts to the vacuum of space. You roll on the condom, open the valve, and it all goes into the void, where it freezes into droplets of ice that are iridescent in the sunlight. (One astronaut, when asked "What's the most beautiful sight you saw in space?" said without hesitation, "Urine dump at sunset.")

In reality, using the urine collector didn't work out so well. For one thing, if you opened the valve too soon, a part of the mechanism was liable to poke into the end of your penis, which tended to prevent you from urinating. And at that point, as if to confirm your worst fears, the suction began to pull you in. Now you were being jabbed and pulled at the same time, so you shut off the valve, and as the mechanism re-sealed itself it caught a little piece of you in it.

The army of flight controllers who kept watch from mission control in Houston knew more about how the spacecraft was faring than the astronauts did.

It took only one episode like that to convince you not to let it happen again.

Next time you had a strategy: start flowing a split-second before you turn on the valve. But once you began to urinate the condom popped off and out came a flurry of golden droplets at play in the wonderland, floating around and making your misfortune everyone else's.

Anders got used to the urine collector, though, and he got used to cleaning up afterward. But there was no getting used to the other part of the Waste Management System. Tucked away in a storage locker was a supply of special plastic bags, each of which resembled a top-hat with an adhesive coating on the brim. Each bag had a finger-shaped pocket built into the side of it. When the call came you had to flypaper this thing to your rear end, then you were supposed to reach in the pocket with your finger—after all, *nothing falls*—and suddenly you found yourself wishing you'd never left home.

And after you had it in the bag, so to speak, you had one last delightful task: break open a capsule of blue germicide, seal it up in the bag, and knead the contents to make sure they were fully mixed. At best, the whole operation was an ordeal. Anders decided he was going to do everything in his power to avoid it. Six days was a long time, but he was determined. He'd go all the way to the moon and back on Lomotil if he had to.

The hours passed in steady activity. By noon Houston time, some five hours into the flight, all three men had doffed their bulky spacesuits and stowed them underneath the couches. Around 1 p.m. Lovell began taking star sightings for navigation. And there were more tasks that extended into the afternoon—replace an air filtration canister, look after a battery, service a fuel cell. At 6 p.m. the astronauts made the first, brief firing of the service module's service propulsion system engine. Though it lasted only two seconds—slamming Borman's crew back into their couches, then releasing them—it was enough to correct Apollo 8's path after Borman's earlier maneuvers to get away from the third stage. Just as important for engineers in Houston, the firing gave a crucial look at the engine's performance in space. It passed its first test with flying colors.

By then more than 11 hours had passed since launch, and aboard Apollo 8 it was getting to be a long day. It was time for Borman to get some sleep. The flight plan called for at least one man to stay awake at all times to keep an eye on the spacecraft and maintain contact with Houston. For now, Lovell and Anders would stand watch while Borman slept. As he floated into the sleeping bag attached to the underside of his couch, Borman was more than ready for a rest.

But his mind would not cooperate; it wasn't easy to just turn off the mission. Two hours later, still keyed up, he called down to Houston and got permission to dig out the medical kit and take a Seconal. He hated pills, but it was important that he rest.

Already, a bit more than 11 hours after Translunar Injection, Apollo 8 had traveled 77,000 miles, a third of the way to the moon. But even as Borman, Lovell, and Anders sped moonward, Earth tried to pull them back, slowing their flight. It was as if the moonship were coasting up a hill, one that became less and less steep as it went along. In about two days, on the afternoon of December 23, Apollo 8 would reach the gentle crest of that hill, the place where Earth's gravitational influence gives way to the moon's. From then on it would begin falling toward its destination.

For now, though, there was no sense of speed, or, for that matter, any normal sense of time. For Borman's crew, time was told by the mission clock on the instrument panel. Their wristwatches were still set to Houston time, but all vestiges of day and night had vanished. They moved in the unrelenting glare of the sun. To keep the sun's heat and the frigid cold of space evenly distributed on the hull, Borman had set the spacecraft rotating slowly, making one full turn an hour. The astronauts nicknamed this the "barbecue mode." Every once in a while, as the craft turned, the men caught sight of Earth. With each passing hour it dwindled. They couldn't see the change as they watched, but if they turned away from it and looked again later, they noticed that it was a little smaller. Presently it was about the size of a baseball held at arm's length.

After separating from the third-stage booster that blasted them out of Earth orbit, the astronauts took this picture. Sunlight reflected from ice particles around the booster created an array of "false stars."

The absence of a lunar atmosphere made it possible for the Apollo 8 crew to take photographs of remarkable clarity—even from 69 miles above the moon's surface (opposite).

Borman awoke after about five hours of fitful sleep. He didn't feel well. He told Lovell and Anders he had a headache and took a couple of aspirin, then he just floated in his couch and watched the instrument panel. A few minutes went by, and the next thing Lovell and Anders knew he was retching. Anders handed him a plastic bag, and Borman went down into the lower equipment bay and threw up. Lovell flashed Anders a knowing look: Borman must be motion sick.

A horrible stench began rolling out of the equipment bay. Anders reached for an oxygen bottle on the wall of the cabin labeled "IN CASE OF FIRE." *To hell with that,* he thought, slapping the mask on his face and turning it on full. Meanwhile, Borman's troubles continued. Now he was struck with diarrhea. What a mess. Lovell and Anders had to help chase down stray bits of vomit and feces with paper towels. In a strange detached way, Anders was reminded of hunting butterflies.

Later, Anders floated in his sleeping bag, eyes closed, trying to relax. He was tired. Before the flight, he would have thought that sleeping on a bed of air was the best slumber imaginable, but it wasn't working out that way. Like Borman, he found it difficult to take his mind off the flight. He missed the pressure of a pillow against his head and the security of a blanket drawn up around him. The bag was clearly designed for someone as big as Lovell; Anders was bouncing around inside it like a lone pea in a pod. He steadied himself and tried to lay still. Every now and then a residual bit of vomit drifted by and he flinched away. And he noticed that his body had not fully adapted to zero-G. His heart, accustomed to a lifetime of fighting gravity, was suddenly too strong. As a result he heard a muffled, incessant *boom boom boom*—his blood pulsing in his ears. And each time he was about to fall asleep, he was startled awake by the sensation of falling, just like the feeling he'd had in dreams on Earth. It was as if his central nervous system were broadcasting an alarm, telling him what he already knew, that he was in an environment unlike anything he had ever known.

Anders finally managed a few hours of fitful sleep. When he awoke, he found Borman much recovered and blaming his illness on a 24-hour virus. Anders suggested he recount the incident to mission control, but Borman replied, "I'll be damned if I'm going to tell the

whole world I had the flu." Anders finally persuaded his commander to put a short summary on tape. The message could be sent to Earth via a special telemetry channel. That way, no one except a few managers would hear the tape.

"I'll go ahead and dump this," Anders radioed Houston. He couldn't come out and say what was on the tape, but he had to find some way of getting them to listen to it soon. He suggested, "You might want to listen to it…to evaluate the voice." There was nothing to do but wait for a response. Hours went by with no word from Earth about the message. Eventually Anders found out why: it was hours before the flight controllers even had a chance to hear it. (*So much for putting messages on tape,* Anders thought.) Finally, at 28 hours Mission Elapsed Time, Mike Collins called up on a special frequency: "Apollo 8, this is Houston. We're on private loop right now, and we'd like to get some amplifying details on your medical problems. Could you go back to the beginning…"

"Mike, this is Frank. I'm feeling a lot better now. I think I had a case of the 24-hour flu…." Borman recapped the whole episode for Collins, and to Borman's surprise, Chuck Berry, NASA's chief physician in Houston, came on the line to talk to him directly—that almost never happened. Unbeknownst to Borman, the episode had triggered serious talk of canceling the mission. Berry worried that Borman had a virus and that it was only a matter of time before his crewmates caught it. But Borman told the flight surgeon that he felt much better and that neither Lovell nor Anders had been affected. "We're all fine," he said.

Minutes later, in consultation with Berry and other managers, Apollo program director Sam Phillips decided to let the flight continue. But the fact was, even if Phillips had decided otherwise, Apollo 8 was too far away for its rocket engine to manage an about-face. Borman, Lovell, and Anders were committed now. Even if they had to abort their mission, they were going to go around the moon.

One of the paradoxes of Apollo 8 was that the three men on their way to the moon knew far less about their status than the flight controllers on Earth. For all Borman's worries about whether Apollo 8 was staying on the right trajectory, he had absolutely no way to find out except to ask mission control. Kraft's trajectory specialists were able to detect tiny changes in Apollo 8's path by measuring the Doppler shift in its radio signals. Even a tiny change in frequency meant something to Kraft's people. Their data were so good that when they plotted the curve you could see a little wiggle in it, produced by the spacecraft's slow thermal-control spin. And they had nothing but good news. The trajectory was nearly perfect. Only two minor mid-course corrections had been necessary so far, and it looked as though Apollo 8 would get to the moon without having to make any more. The perfect marksman's shot that everyone had hoped for was about to be realized.

The moon itself was nowhere to be seen. Due to Apollo 8's angle of approach, the moon was lost in the sun's glare. Anders had looked forward to watching it grow ever larger as they closed in until it became a huge, cratered ball in the sky, like some science fiction vision. But Anders had not seen the moon once on the whole trip out, not even a glimpse.

A constant stream of telemetry beamed from Apollo 8 to Earth was picked up by the giant radio dishes of the Manned Space Flight Network, then transmitted across land lines and via satellites to Houston, where an army of flight controllers kept watch on hundreds of components. Borman was amazed at how much they could tell about his spacecraft from more than 200,000 miles away. He had no idea, for example, whether the fuel lines in the service propulsion system engine were as warm as they should be or frozen solid, but the systems people did, and their reports were terrific. The fuel cells were functioning even better than expected. The computer was running like clockwork. There was plenty of fuel left for maneuvering. Borman had wanted a perfect spacecraft before he'd commit to the Lunar Orbit Insertion burn, and now he had it.

The capsule communicator, or capcom, Jerry Carr radioed word to Apollo 8: "You're go for LOI. You're riding the best bird we can find."

With characteristic caution, Borman had already turned the spacecraft to the precise orientation for the burn. In

fact, he had done it two hours ahead of time. The moment of truth, the crucial insertion burn, would come when Borman's crew was behind the moon and out of radio contact; they would have to rely completely on themselves and their machine. If the firing went as planned, the radio blackout would last 45 minutes. But if a malfunction came up and Borman decided to abort the mission, Apollo 8 would come around a good bit sooner. In mission control, Kraft's trajectory people would know how things had gone simply from the time at which they picked up Apollo 8's telemetry.

Strapped in their couches, Borman and his crew waited out the last minutes of a three-day journey. Each of the three astronauts knew they were cutting it very close to aim nearly a quarter of a million miles across space to a world just 2,160 miles in diameter, zip just ahead of its leading edge, and go into orbit 69 miles from its surface. (The joke around the simulator was "Wait till you see the 70-mile-high mountain on the far side of the moon.")

Sixty-nine miles out of 234,000 left little room for error, so it was understandable that Borman's crew wanted something more than numbers to assess the accuracy of their path. Before the flight, the trajectory people had told the crew that they wouldn't be able to see the moon as they came in. Deprived of the one seat-of-the-pants method a pilot has—eyeballing the target—they asked for something else. There was one answer: loss of signal, or LOS, the moment when Apollo 8 would lose radio contact with Earth. Once the craft was on its way to the moon, the controllers had been able to predict the time of LOS down to the second. If it happened precisely as mission control predicted, Borman's crew would know the calculations had been right.

"One minute to LOS," advised Jerry Carr. As he spoke, the mission clock read 68 hours, 57 minutes, 4 seconds.

"Ten seconds to LOS," Carr radioed. "You're go all the way."

"Thanks a lot, troops," Anders said.

"We'll see you on the other side," added Lovell.

Borman watched the mission clock intently. At precisely 68:58:04 the three astronauts heard static in their headsets. Borman could hardly believe it—right to the second. He said aloud, "That was great, wasn't it? I wonder if they turned it off." Anders laughed; he could just imagine Kraft saying, "No matter what happens, turn it off."

The men were running through the checklist for the burn when suddenly the spacecraft was enveloped by darkness. Anders realized they were deep in the shadow of the moon. As his eyes adapted, he saw that the sky was full of stars, so many he could not recognize constellations. Looking back over his shoulder in the direction they were headed, he noticed a distinct arc beyond which there were no stars at all, only blackness. All at once the eerie realization hit him that this hole in the stars was the moon. The hair on the back of his neck stood up. *Come on, Anders,* he told himself, *you're not supposed to feel this way.*

Perhaps the most moving image of the entire mission was the sight of a tiny Earth rising above the moon's horizon.

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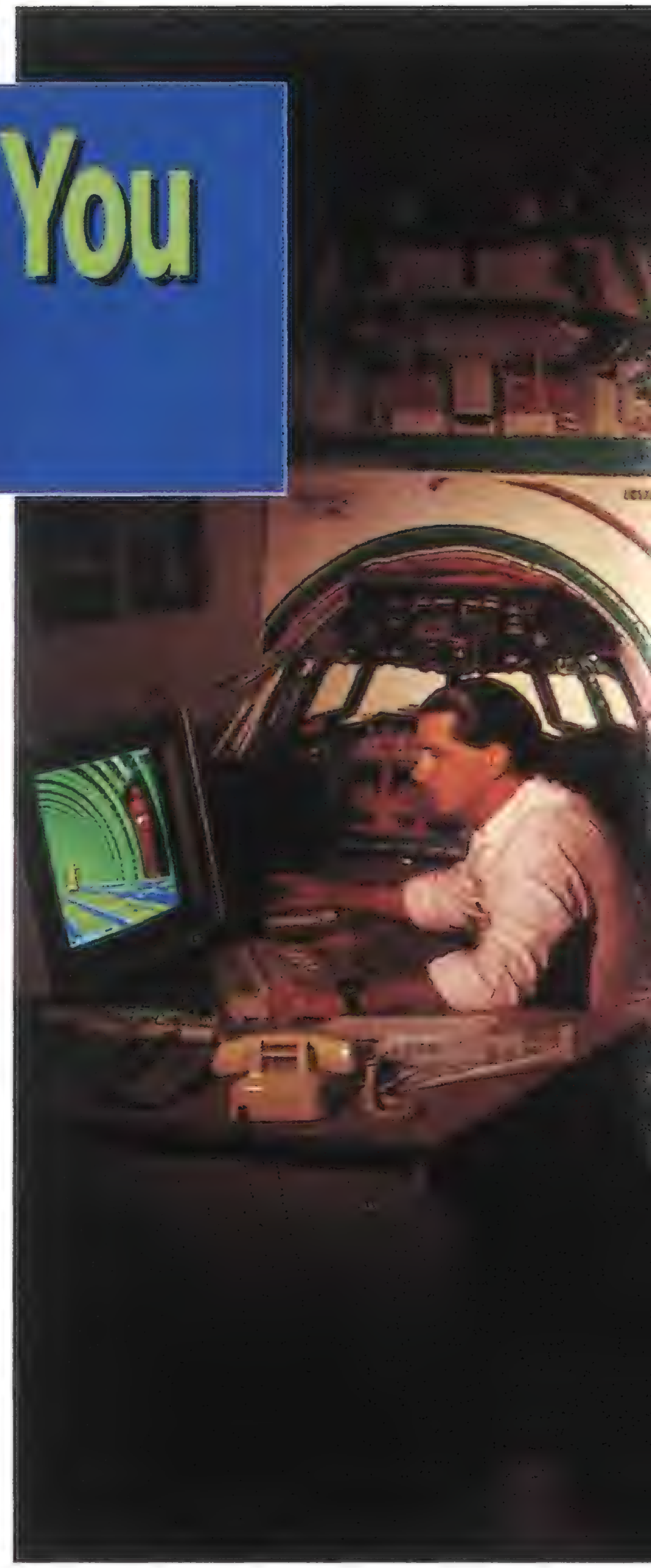

To build the new 777, Boeing wanted to gather people around a table and design the airplane the way they used to. With one big difference.

by Fred Reed

Photographs by Dan Lamont

It had to happen. In a world where "virtual reality" has become established in the techie lexicon, the Boeing Commercial Airplane Group, at considerable risk, has designed the 777, a wide-body twin-jet, as a "virtual airplane." What this means is that until the first airplane rolls out in April, the 777 will exist only as a massive database. No blueprints. No mockups. Everything is in the computer. While the company's airliner-in-a-computer has gained wide attention, the use of computer-based design was never an end for Boeing but a means.

The 777 is the largest twin-engine airplane in the world: its wing span is just one inch shy of 200 feet. Sized between the 767 and 747, it will be powered by a new class of enormous turbofans that produce 70,000 to 90,000 pounds of static thrust. And Boeing has set itself the goal of delivering the airliner to customers in 1995 with approval for Extended-Range Twin-Engine Operations (ETOPS) under a rule that limits how far from an airport a twin-engine airliner may operate. To reduce drag and attain fuel consumption goals, the company is designing parts of the airplane to exceptionally close tolerances for a tight fit. But those are mere engineering risks.

Much scarier are the chances Boeing is taking with the way it operates internally. For example, when it launched the project, Boeing decided to invite its airline customers to participate in the design process. During a lecture in 1992 to the Royal Aeronautical Society in England, Boeing president Phillip Condit described rather candidly why such a move is worrisome: "When you let your customers see the inner workings of your company, you risk exposing your shortcomings. Maybe they will find out that you are not as smart and efficient as you say you are.... The irony is, however, that

the tendency to exclude customers for fear of risking embarrassment can result in delivering a product that fails to meet their needs fully. And that is the most serious 'embarrassment' of all—one that can rather quickly put you out of business."

In the same lecture, Condit recounted the growth of Boeing from its earliest days, when a small group of people could sit around a table and make decisions about a design. As the company grew, so did barriers between design, manufacturing, and finance. "As specialties grow within an organization, they tend to seal off one function from another and create rivalries and misunderstandings," Condit said. On the 777 project, Boeing was determined to "break down some of the artificial barriers which isolate functions and organizations." The company wanted to bring together representatives

Images generated by CATIA software can be projected onto big-screen video displays at Boeing's Digital Pre-Assembly Visibility Center.

from each of its "specialties" and grant customers unprecedented access to the process. To do this, it instituted something called a design-build team.

The idea behind the DBT is simple. First, assign a different team to design each part or system of the aircraft (there were 238 DBTs on the 777). On each team include representatives from manufacturing and tooling whose job is to say, "That's a nice widget, but we just can't manufacture it. See, here's the problem. How can we redesign it so it still works and we can build it?" Before a component is released and becomes part

It takes a real mechanic like Jack Hessburg (left) to point out the problems maintenance people face. A digital mechanic is used to show designers how much room they need to create in service work spaces (below).

of the airplane, everybody signs off on it.

People at Boeing differ as to whether the current approach represents a revolution (the majority view) or merely a sort of headlong evolution (the view of some of the older employees). Gerald Ostrom, a longtime Boeing employee, says, "We always had this kind of communication. It was just informal, at a higher level. What we're doing now carries it further, but it's not something nobody ever thought about before."

Ostrom also says that DBTs help to compensate for the current designers' lack of experience. When the supersonic transport program collapsed in the 1970s, it marked the beginning of a decline in Boeing's fortunes. After a slow start, the 747, and later the 737, began to sell, and the worst was over. But the lean years, says Ostrom, left an age gap in the ranks of designers. Old-timers characterize the new crop as better educated, interested in technology but not in flying, and considerably less experienced than people in their positions were a generation ago.

The DBT idea spread as more people were drawn into design—including many who, in earlier years, would have had virtually no input. It was as if somebody said, "Hey, why don't we include maintenance guys too, so they get an airplane that can be fixed easily." The effect was a sort of democracy. "They listen. I can't tell you how much difference it makes," says Jennifer Noel, head of the tooling department. "I can actually say, 'No, don't do that,' and they don't do it." The idea seems so obvious that anyone's third grade daughter could have thought of it between homework problems, but the airplane industry regards it as a breakthrough.

So representatives of four airlines, including United and All Nippon Airways, moved into Boeing buildings and now work closely with DBTs on things that matter to airlines. (For the most part, it turns out, all airlines want the same things in an airplane, so there is little conflict.)

Gordon McKinzie, the United Airlines representative, says the airlines "sort of invited themselves" into the offices at Boeing. "In the past, manufacturers would pretty much just give us the airplane and say, 'Here it is.'

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Things inevitably would be wrong with it, some of them as minor as rivet heads that snagged the customer's sweater. It would take years to get them fixed.

"Getting the airlines in early makes all the difference," he says. "We know what we need because we fly the airplanes every day. Some of what we want might be broadly called flexibility—for example, the ability to take out a galley and put in more seats for short hauls on heavily traveled routes. We're getting it. There are other, more specific things. For example, the refueling panel on the 777 was going to be three feet higher than on the 747. Current trucks couldn't have reached it. We would have had to buy a whole new fleet of trucks, not something we looked forward to. So the designers moved it to a lower point for us."

Tooling department head Jennifer Noel (below) believes in the computer-based design process, but paper drawings still have their place.

Boeing seems to take cooperative design seriously. Jack Hessburg, a Boeing mechanic with 30 years' worth of experience fixing airliners, says, "We send engineers to O'Hare to watch gate operations during a 50-minute turn. They come back amazed. 'Hey, you guys got a different agenda from us.' Yeah. Working on a gate, they figure out that the airlines aren't in the airplane business. They're in the transportation business. *We're* in the airplane business. There's a big difference."

He cites the example of a multi-function cockpit display that can give various kinds of maintenance information. Using only one display is economical—what an engineer would see as a clean solution. But in practice, it forces maintenance people to wait in line to get at the display, which slows everything down. Airlines don't want engineering solutions. They want transportation solutions, largely meaning an aircraft that can be maintained quickly and put back in the air on time.

In order to make the DBTs work, Boeing had no other choice but to build the airplane in cyberspace—to build it in a computer.

The design is managed by a sophisticated program called CATIA (Computer Aided Three Dimensional Interactive Application), written by Dassault of France and licensed in the United States by IBM. Engineers working on the 777 sit at over 2,000 work stations connected to a central computer cluster that happens to be the largest mainframe computer network in the world, linking eight supercomputers that can process almost three trillion bytes of data. The DBTs call up portions of the design, work on them, and send them back to the computer. When they all agree on an element's design, it can be electronically transferred to manufacturing, where it will be made into a part.

Boeing has a lot riding on CATIA. The idea isn't magic, nor is the increasing computerization of design and manufacture unique to Boeing. But the company says the 777 is the first aircraft to be totally designed by computer. Until work on the 777 started, Boeing had used CATIA only to design an engine strut for the 767, so there is some risk in diving into a whole airplane this way. CATIA had better work; it is an inseparable part of a completely altered way of doing business.

Individual work stations allow people like this payloads designer to maintain a connection to the cumulative efforts of colleagues in other specialties. If conflicts arise between departments, the system will alert users.

A demonstration of CATIA is almost eerie. In a darkened room a technician sits at a work station. A large projection television screen reproduces his screen for everybody else in the room. With a few keystrokes he calls up the 777's airframe. Suddenly we are *inside* the fuselage. Girders and braces appear in green and in three clear dimensions. Even shadowing is realistic.

A few more keystrokes and the hydraulic systems appear in red. Other systems appear magically, color-coded for easy recognition. The technician changes the position of

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vert in your head, to look at paper drawings and imagine what the solid object would look like. It encouraged mistakes, and mistakes cost money." Mistakes used to be corrected by a process called rework—modifying the airplane after it was built and then reflecting those changes in succeeding airframes. But Boeing has to cut costs to compete, and rework costs too much.

When an airplane consisted of many thousands of drawings that had to be carried from building to building and carefully tracked, people had enough trouble knowing what they were doing themselves, much less what anyone else was doing. But with CATIA there is only one "blueprint"—the disembodied model in the computer—and *everybody* has access to it.

"Probably the greatest advantage is the communication CATIA allows," says Jeff Peace, the 777's chief project engineer. "Any engineer can access any part of the airplane. Everybody knows what everybody else is doing. In the past you didn't find out about mistakes until you were actually building the aircraft. With CATIA we find out early, when it's still cheap to fix things."

the viewer, moving us into the cockpit or wheel well. Next he calls up the interior of the finished craft, complete with seats and luggage bins.

"It's not perfect yet," says a technician. "For example, when a lot of people are on the computer, the system gets sluggish. Still, it's real good."

The images are a bit cartoonish, but that makes no difference for design purposes. And they *move.* To demonstrate this, the technician "opens" an overhead storage bin to show that it does indeed allow a passenger convenient access. It's like having remote control of an actual airplane, except that in a real airplane you can't make every system vanish except the one you want to see. CATIA even creates "blueprints" by showing sectional views through any part on any axis.

After spending a few days with people who actually use CATIA, you discover that the system affects the organization and psychology of the people who use it. For example, three-dimensionality, while not the most important feature of CATIA, changes the way people think. Says Scott Forster, lead design engineer, "People think in three dimensions and we build airplanes in three dimensions, but designers have always used two-dimensional drawings. You had to con-

Colors identify systems and structure in the nose section (top). Chief 777 project engineer Jeff Peace (above, left) ensures that Gordon McKinzie of United Airlines gets the airplane he wants.

One of the most important features of the software is what Boeing calls "electronic preassembly." CATIA can check to see whether different components interfere with each other—for example, by trying to be in the same place. On a big project it's routine to discover at manufacture that a hydraulic line runs through a floor beam. With CATIA the designers can "freeze" the design periodical-

ly and check the entire aircraft for "interferences." A technician demonstrates this by calling up the aircraft's interior and moving a lavatory module to space already occupied by seats. The points of interference immediately begin to flash. Boeing is counting on this feature to save them lots of time and money on rework. "We estimate we spend 40 percent more time and effort in design than we did before," says Scott Forster. "But the payback is that we don't find at assembly time that nothing fits and have to rip out half the airplane."

One of CATIA's odder features is the use of three-dimensional figures, representing mechanics, that can be maneuvered in repair spaces to see whether the necessary mo-

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A digital mannequin can help give a vivid sense of scale to a massive six-wheel main gear (left).

tions can be made by human beings. According to mechanic Jack Hessburg, having maintenance advocates present during design makes a difference. "The engineers try to protect their designs," he says. "If they know a crawl space is on the small side, they try to use a five-foot-three-inch mannequin. I make 'em use a six-foot-four one. Remember, the mechanic has to spend 30 years doing it."

At one DBT meeting, about 30 men and two women sat in a crowded room, watching a teleconference monitor broadcasting from Wichita (work on the Triple Seven is spread all over the country, although most occurs in and around Seattle).

"Wichita, this is Neal...do you hear me?"

Wichita did, but the audio was not great and the picture jerked between stills. People interrupted each other, but not inconsiderately. Here, as in earlier roundtable discussions, people who expressed themselves confidently were listened to as equals, but one woman who seemed on the deferential side was conversationally trampled. The talk was incomprehensible to an outsider, but informal and cooperative.

"As you recall, we had a PDM 19-C for..."

"The put was: let's not double-book those items..."

"When do the flags toggle to bought-off?"

"We will not accept any exceptions except..."

"That meeting was a dog's breakfast of engineers..."

Kidding was not uncommon.

Two things became clear at the DBT meeting. First, CATIA or not, the 777 is a monster of a management problem, with people worrying that they couldn't do A until B was done, which wasn't clear because C was slipping behind schedule, and D couldn't be located. Boeing may have found an easier way to design an airliner, but it

Boeing employees working outside the 777 program have their first encounter with the new airliner through the CATIA images that take them on a tour of the airplane's interior during a company briefing session.

hasn't found an easy way. Second, team members seem to have accepted that they are a team. A common question was something along the lines of "What does customer service think of that? Have we asked manufacturing?"

How will the 777 fare in an uncertain market and in a soft world economy—and facing competition from Airbus and McDonnell Douglas? No one knows, but we had better get used to the virtual airplane. "As far as we are concerned," says Jeff Peace, "this is the future. This is how we are going to design airplanes from now on."

MARS DIRECT

by Lance Frazer

People from Earth could explore Mars some time in the next century. Bob Zubrin says they can go in the next decade.

The Space Exploration Initiative announced by President George Bush in 1989 borrowed its grandeur from *Mars Project,* Wernher von Braun's 1953 treatise about the spacecraft and technologies required for the human exploration of Mars. Both envisioned the Mars mission as the consummation of an epic plan, the last of many steps from Earth orbit outward. SEI was an ambitious multi-stage project that included building gigantic vessels in low Earth orbit for the ultimate Martian expedition. NASA studied the idea for three months and issued what became known as the 90-Day Report, estimating a cost of $400 billion over 30 years.

Congress refused a down payment on a bill that size, and even the Bush administration recoiled, assembling a panel to seek revolutionary—and cheaper—technologies. The Synthesis Group, as the panel was called, synthesized testimony from 125 groups and individuals into a 1991 report that outlined another four ambitious, expensive, infrastructure-dependent "architectures" for fulfilling SEI. This report has joined its predecessors on bookshelves, a new administration has replaced the SEI authors, NASA has closed its Office of Exploration, and no money is currently appropriated for a manned Mars mission. But one tiny contract, funded with money shifted from a canceled study, was recently awarded by NASA's Johnson Space Center for the study of a very different approach to Mars. The mission won't happen soon—its estimated cost is $40 billion—but the mission strategy may change a long-standing pattern and focus future Mars studies on ideas that are simpler and more direct.

PAINTINGS BY ROBERT MURRAY

Mars Direct would use a shuttle-derived booster to send 40 tons of cargo directly to Mars.

"Mars Direct" is a scenario concocted by two engineers, but both credit history, not engineering, for the inspiration. The innovation in their strategy is that astronauts bound for Mars won't have to bring oxygen and propellant with them for the return journey. The vehicle that will bring them back to Earth, sent to Mars in advance of the people, will have its own factory to manufacture fuel and oxygen from the chemicals in the Martian atmosphere.

Robert Zubrin, a 41-year-old senior engineer at Martin Marietta Astronautics' Deer Creek facility south of Denver, says his guiding philosophy was to define a project that could be accomplished within ten years. "This is not a technology development project," he says. A history buff, Zubrin points out that the 19th century British navy spent a fortune sending fleets of heavily armed and provisioned warships in search of the Northwest Passage, while at the same time, "small teams of explorers traveled freely via dogsled, living off the land and accomplishing far more than the British navy, and at a much lower cost."

Zubrin's plan begins with the launch of a heavy-lift rocket that sends 40 metric tons of cargo to Mars. The cargo includes an unfueled, two-stage ascent and Earth return vehicle, six tons of liquid hydrogen, a 50-kilowatt nuclear reactor, and a few small scientific rovers and compressors. Inside the landing stage of the return vehicle is an automated fuel factory.

"For decades, the major limiting factor of space exploration has been fuel,"

NASA/JPL

says Zubrin. A 1987 NASA study estimated that 2.2 million pounds of fuel would be required to send six astronauts to Mars and bring them back. "We operated under the assumption that the only way to go anywhere was to lug along enough fuel to get you back, but that's not the way the most effective explorations are carried out."

Zubrin's factory produces rocket fuel from carbon dioxide, which makes up more than 95 percent of the thin Martian atmosphere, and hydrogen brought from Earth. The carbon dioxide reacts with the six tons of hydrogen to form methane and water: $CO_2 + 4H_2 = CH_4 + 2H_2O$. This is the Sabatier reaction, named for the 18th century chemist who discovered it. The methane is channeled into the fuel tank of the return vehicle, and the water is electrolyzed to produce oxygen—needed to burn the methane on the return trip—and more hydrogen, which is recycled through the Sabatier reactor.

After the reactor has produced the 96 tons of methane/oxygen required for a 14-ton ship to return from Mars—the process is expected to take about 10 months—two more rockets launch from Earth to deliver two additional vehicles: one, carrying a four-person crew, is a lab and habitat for the surface of Mars; the other is a second return vehicle with another fuel factory inside.

The concept of in-situ resource utilization was developed in the early 1970s by Robert Ash, a mechanical engineer at Old Dominion University in Virginia, and Warren Dowler of the Jet Propulsion Laboratory in Pasadena. Both published papers on the subject, and Zubrin says their work provided the starting point for his plan. Ash, who is today a professor of aerospace engineering at ODU and is still working on in-situ propellant production, was on a JPL advanced planning committee trying to develop Mars missions to follow the successful Viking probe program.

"We were looking at robotics, some sample/return possibilities, and, very quietly, manned missions," Ash says. "It had become obvious that the things we could do with existing rockets and systems just weren't compatible with round-trip missions to Mars. Vic Clark, another member of that committee, had been working on the idea of using RPVs [remotely piloted vehicles] to explore the Martian surface, and he asked us to look at ways to make propellant for those [RPVs] on Mars.

"Warren and I bounced several different ideas back and forth, none of which led to anything, but then in 1976 the Viking lander information started coming back, giving us the first detailed look at the composition of the Martian atmosphere. At that point, we knew we had a resource."

Being certain of the resource still does not assure that the machinery will work. Zubrin and his colleagues at Martin Marietta, however, have just taken the first step in showing that it can. Under a $47,000 contract from the New Initiatives Office at the Johnson Space Center, Zubrin built a 40-pound demonstration model of a chemical processing unit, the size that would be used in an unmanned sample/return mission. He showed that with about 150 watts of power his reactor could generate about two pounds of fuel a day. If it were to run continuously on Mars for 500 days, the length of time it takes for Mars and Earth to realign for efficient transit between the two planets, it could produce 1,000 pounds of propellant, more than enough to fuel a 100-pound craft bringing back a 10-pound sample of Mars. "We have gone from brute force and high cost to finesse, living off the land, and very low cost," JSC New Initiatives director Humboldt Mandell told the trade weekly *Space News*.

NASA managers have not always been so complimentary. When NASA's plan to carry out the Space Exploration Initiative faltered, the agency asked for ideas. Ben Clark of Martin Marietta put together a team to brainstorm more workable, less cumbersome, and cheaper methods for exploring the solar system. Two members of the team, Zubrin and former Martin engineer David Baker, now president of DAB Engineering in Denver, developed Mars Direct.

Baker remembers the frustration he felt in dealing with NASA. "We were under contract with Marshall [Space Flight Center] to examine possible Mars scenarios," he says, "but NASA kept coming up with requirements that pushed us back into line with the path they'd chosen—'Battlestar Galactica'-type vehicles of 1,000 metric tons, 100-ton payloads, that kind of thing."

Zubrin and Baker, however, kept their plan simple and direct, and in April 1990, they made their first formal presentation to the Marshall center.

"NASA has a great 'built here' syndrome," says Baker, "and the problem with Mars Direct is that it wasn't 'built here.' When we got to Marshall, the reaction I got was 'Here come those cute boys from Martin. Let's listen to their idea, applaud, and go back to work.' So we made our presentation, they applauded, and then went back to work."

The fact that people at NASA started to look more seriously at the Mars Direct concept is due, believes Baker, to Zubrin's personality. Zubrin admits he has a habit of unabashedly soliciting support at every opportunity—"From Kiwanis luncheons to pipefitters' conventions," he says. Slightly built, with thinning hair and a soft voice, the Brooklyn-born father of two is an unlikely, albeit effective, crusader.

"Bob is highly motivated, which can make him hard to work with," says Baker, "because once he gets something in his head, he's almost impossible to dissuade.

"I must admit, I would have given up on Mars Direct long before this point, but Bob's different. Now that it's such a long shot, that NASA's interest in Mars has disintegrated, I don't know where he gets his energy. A good part of it is ego-driven, but I think there's also a genuine desire on his part to contribute something of great significance to the human story."

Zubrin didn't set out to upend NASA orthodoxy. A former high school math and science teacher, he earned advanced degrees in astronautical and nuclear engineering. He heard from a friend about the Case for Mars conferences, meetings held every three years by people who advocate travel to Mars and discuss strategies for getting there. At the third meeting, in 1987, he heard a presentation by Martin Marietta scientist and Viking alumnus Ben Clark, who later became his boss, on the state of the Mars exploration program. Zubrin became a convert, then a campaigner.

"I don't think anything better could possibly happen to NASA than to be given a program and told, as John Kennedy did, 'You've got ten years to make this work,' " he says. "There are a lot of good people within NASA, people who want to do the work and do it well and fast, but they've gotten so bureaucratized they can't move. If the Roosevelt government had run the way we've been going for the past couple of

Bob Zubrin says existing technology—cleverly used—is the ticket to Mars. Once there, rovers for exploratory expeditions on the surface (opposite) would also be powered by the methane and oxygen manufactured in situ.

ERIC LARS BAKKE

decades, we'd have lost World War II before it started."

Zubrin has a tendency to preach, but he is sincere and evokes strong reactions from people. One has the feeling that it was his charisma that won him followers at Marshall. For Zubrin says that even though he was apprehensive about that first briefing, he found supporters. "I was nervous," he says. "I figured these guys, who were all pretty committed to the '90-Day' approach, would up and tell me, 'My daddy didn't do Mars exploration this way, and we don't need some damn uppity Yankee to come tell us how to do it.' " But Zubrin says his audience was interested. When he traveled to the Johnson Space Center for a presentation the following week, a few of the Marshall employees attended the briefing there, strategically situated throughout the audience.

"Plants? Yeah, I guess that's as accurate a way of putting it as any," Zubrin admits with a grin. "These guys sat in the audience and made sure they asked the right questions needed to highlight the proposal."

But at Johnson the majority reacted with skepticism.

"You have to remember that when Bob came here, we were still in the throes of the 90-Day Report, so what we were looking at was just the inverse of what Bob was proposing," says mission analyst David Weaver, who was in the Johnson exploration programs office at the time. "I don't think he got a fair shake at all.

"The 90-Day Report [called for] perfecting each technology before moving on, which is a long, expensive process. What Bob did was come in and say, 'Hey, instead of developing new technologies to deal with each problem, let's just avoid them.' That took some getting used to."

Zubrin was unshaken. He went on to NASA's Ames Research Center, the fourth Case for Mars conference, and the Synthesis Group. When he addressed the National Space Society Conference in Anaheim in May 1990, Zubrin says, the drubbing that SEI had been taking in Congress gave the meeting an atmosphere of crisis. "I was the last speaker, just by accident, and I made some remark as an aside and got some applause. That got me going. The more intense and emotional I got, the more they applauded, and I just knocked it out of the park. I spoke for an hour and a half and at the end I was emotionally drained. I got a two-minute standing ovation."

Within the group of Mars advocates, Zubrin still has a high approval rating. But he also has many critics to answer.

Robert Seamans, a senior lecturer at MIT and co-chair of the Synthesis Group, says the remote fuel production concept is intriguing but risky. "The idea of sending astronauts millions of miles into space, with the promise they can fill their tanks when they arrive, worries me," he says. "I remember back in the '60s, there was a plan to refuel lunar missions from a fuel depot on the moon. This idea seems to be one step more difficult."

Later, in a 1988 report on human exploration of the solar system, NASA's Office of Exploration proposed using resources on the moon and the Martian moon Phobos to make rocket fuel, and even the 90-Day Report identified in-situ resource utilization as a technology to be developed. But the fuel was intended for future expeditions, not the astronauts' ticket home.

Robert Ash is less concerned with the apparent risk of long-distance fuel production, saying the process offers several advantages over the shipment of large amounts of fuel (and the corresponding use of large spacecraft). "Look, this is a 100- to 200-day trip, where people on Earth will be unable to intervene in any meaningful way in the event of trouble, and astronauts, unless they've been provided with artificial gravity, are going to find the readjustment to gravity fields at Mars very difficult," he points out. "I think, given those conditions, it's going to be a lot safer to have a fully fueled return vehicle standing by on the surface than it would be to try and land a much larger, heavily fueled return vehicle on the surface of an unfamiliar planet.

"I will admit," he adds, "we don't really know a lot about the particle distribution or composition of Martian dust. We don't have firm knowledge of its reactivity with our seals and other materials, nor of the need for filtration of our systems. I'd like to see a lot more information in that area."

Kumar Ramohalli, co-director of the NASA Space Engineering Research Center at the University of Arizona, thinks Zubrin plans to take too much along. He proposes that the first six tons of hydrogen required to produce methane can also be obtained on Mars. "Hydrogen not only loves to leak, but it is also extremely volatile and needs a major refrigeration system and corresponding power supply to make it

into and keep it in liquid form," he says. "Studies show there's plenty of water in the atmosphere, soil, and polar caps of Mars. What we're working on is a way to remove the water from the Martian environment. Then we can break it down into hydrogen and oxygen as it's needed, rather than worrying about bringing it along."

"There are a lot of [Zubrin's] ideas we like," says Johnson's David Weaver. "It's a positive that there is no orbital assembly required, no orbital storage of dangerous propellants, and the in-situ fuel manufacture is a wonderful idea. One aspect which concerns us is Bob's weight strategy." The Zubrin plan, according to Weaver, calls for the crew to return from Mars in something "about the size of a Dodge Caravan, and I'm not sure that's at all realistic."

The goal of Mars Direct, responds David Baker, was "to create a different scenario, one based more on traditional precepts of exploration. My first thought was to up the risk level and hardship of the crew. NASA had always done everything it could possibly do to ensure safety, and you can certainly argue for that approach. However, the history of exploration has always been that the crew was there to run the boat. We figured the crew could do with a smaller, perhaps less comfortable 'boat' on the way back."

The size of the crew's habitat, which has a direct bearing on the mission's fuel requirements, was also a point of disagreement within NASA. But as long as he sells the concept, says Zubrin, the vehicle sizes can be adjusted. "I don't expect NASA to adopt my plan point by point, no matter how wonderful I might think it is," he says. "I'm trying to provide some ideas, some new ways of looking at old problems."

As NASA learned with Apollo, however, getting there is only part of the problem. Doing something useful once there is the real challenge. Zubrin answers that if every other year, NASA launches two boosters—one to land a crew and laboratory, the other to prepare a site for the next mission—sustained Mars exploration becomes available for a launch rate of one big rocket a year. "Listen, " he says, "if Kennedy had said, 'Let's go to the moon by the year 2000,' his support would have been lukewarm at best, and things would have fallen apart long before. Supporting a 'gradual approach' is just another way of saying you don't want to go."

Zubrin's eagerness makes him seem unaware that advocates of Mars exploration have reason to be discouraged. The United States is, in many ways, further from Mars now than it was five years ago. "We stopped work on the advanced launch system we'd need to lift a Mars mission," says Martin Marietta's Ben Clark. "Closed-loop life support is on hold because of the problems with whether the space station will ever fly, and we're letting [Russia's] Energia, which would suit our needs perfectly, rust on the launch pad.

"Because of NASA's reorganization, there's not really even any certainty about which department would field such a proposal, which makes it very

The first Mars Direct vehicle is an unmanned conical spacecraft that makes its own fuel for the return trip. The second craft, a piloted habitat and laboratory, brings a surface rover in case it doesn't land within walking distance of the first. An inflatable greenhouse completes the base.

difficult for anyone to get an idea heard. Within NASA, there is, as yet, no support for any Mars mission among those who actually make things happen, rather than those who make the plans for things to happen, and it may take a long while for Bob to bridge that gap."

Zubrin seems to have the patience for it, but even if he can sell the Mars Direct concept to the faithful who want to send people to Mars, he will continue to be debated by others who think robots are better explorers. One of those is Alex Roland, formerly a NASA historian and today a professor of history at Duke University. "Look," he says, "as soon as you put a man in one of these missions, the primary goal ceases to be science and exploration and becomes the preservation of life. You can have robots do long-duration, high-risk projects like these, and you can send several robotic missions for the price of one manned mission. You don't need to risk human lives." The risk makes manned exploration impossible, explains Roland, not so much because humans are in danger of dying—"I'm sure you'd get lots of volunteers for a manned mission to Mars, even if they knew they might not come back"—but because the efforts to save lives increase the complexity and cost of the mission.

To most people, $40 billion for Mars Direct is every bit as incomprehensible a figure as $400 billion for SEI, and that's a chief reason that unmanned missions have "considerable support" in Congress and manned missions do not, according to Congressman George E. Brown Jr. of California, chairman of the House Science, Space, and Technology committee.

David Baker has given up hope for a government-supported Mars mission. He believes Mars will be reached, but through the efforts of private enterprise. "I think someday we'll see a group of wealthy adventurers, explorers like those who spend millions on around-the-world yacht races, who'll pool their resources for the first mission to Mars," Baker says. "I think we could see a group of the world's wealthiest people put together a pot of $40 billion, create a focused project with no bureaucrats, no one beholden to any constituency, take the risks deemed necessary, and just go."

Zubrin, on the other hand, comforts himself by looking ahead. "I'm not really concerned about what the people in power think today, because those thoughts change almost as quickly as the people themselves. Space exploration is still a very popular concept in this country—it's only the people inside the Beltway that are disconnected from reality. Besides, there's another presidential election in three years, and another one four years after that, and while they come and go I'll still be here, still pushing."

Early this year Johnson Space Center requested proposals for a pump that could pull carbon dioxide into Zubrin's miniature factory and a storage system for the resulting methane and oxygen. Johnson's David Weaver proposed a robotic sample/return Mars mission to NASA's Office of Space Science that will use in-situ resource production to provide fuel for the flight home. And the working design used by the Center's planetary projects office to study manned missions to Mars is based on direct launch to Mars from Earth—without orbital assembly or rendezvous—and use of local resources starting with the very first mission. Mars Direct continues to show signs of life.

That Magnificent Man and

EARL HALL

Though Palen played his airshow roles with campy aplomb, he always insisted his airplanes—here a 1916 British F.E.8—were the stars.

RICHARD KING

When Cole Palen died late last year, the Golden Age of Aviation lost its greatest hands-on communicator. Palen was the proprietor of the Old Rhinebeck Aerodrome in Rhinebeck, New York, and for the past 35 years, from June through October, he and his associates there entertained thousands with twice-weekly airshows featuring his antique and reproduction aircraft. On these pages, friends and colleagues of Cole Palen remember the man.

Jody Gertler, antique aircraft engine dealer

I was a teenager when I first met Cole Palen. My father had taken me to visit Cole's improbable Shangri-la. These were the very first days of the Old Rhinebeck Aerodrome. We found Cole standing in the middle of a converted chicken coop doping wings, a pot-bellied stove heating both the coop and a can of beans set on top of it. My father and I always laughed at how lucky he was that the whole place hadn't blown up from the dope fumes. It was freezing, it was Spartan, but here was a man as close to heaven on earth as it gets.

Dick King, pilot, Old Rhinebeck Aerodrome

Cole knew, of course, that pilots were the ones who had to take his aircraft up and eventually bring them gently back to earth, but to him the pilots were not the most important element. The "aeroplanes," as he called them, were billed as the stars of the shows, not the pilots. He never flew an airplane to show off his piloting skills, though they were considerable; he always flew to show off the aircraft. That is why he insisted on flying them as they were originally equipped, with original engines and, in some cases, no brakes.

Stan Segalla, pilot, Old Rhinebeck Aerodrome

The greatest flying I ever saw Cole do was in his 1917 Fokker triplane. He was coming in over the airport at about 100 feet, where, as part of the airshow act, he would drop a bouquet of flowers to "Madame Fifi" at the hotel. Just as he dropped the flowers, one of the rotary engine's cylinders dropped out of the airplane—blew right through the cowling. Cole quickly shut the engine off and slid the airplane down toward the ground, made a right-hand turn going down the dogleg at the end of the runway, and stopped at the edge of the trees. We ran down there and he was standing there laughing.

Dick King

Cole had this trait that was pretty unique to him: this loud, boisterous laugh that could be heard all over the airfield. It was his way of releasing nervous energy.

I was flying at the aerodrome the day his triplane lost a cylinder, though I didn't learn the details of what had downed him until after I'd landed. Aside from blowing a huge hole in the cowling, that wayward cylinder had set up a terrific vibration, for now the engine was no longer finely balanced. In fact, the vibrations were so severe that Cole's vision became blurred. "It was an absolutely

By the time of his death at age 67, Cole Palen had made the Old Rhinebeck Aerodrome into a unique tribute to early aviation.

His Flying Machines

horrendous landing," he told me later when we finally got around to discussing what had happened. As a result of his not being able to see, he had hit the ground so hard that the triplane bounced badly three times before it could roll to a stop.

Years later I overheard Cole tell someone that this incident was the most frightening experience he had ever had in an airplane.

Leo Opdycke, editor, WWI Aero magazine

For most of the early 1980s (and off and on for 20 years prior to that) I was building a reproduction 1914 Bristol Scout, and Cole and his people at the Old Rhinebeck Aerodrome were always helpful to me. Cole showed me the basics of aircraft welding, and he was always open to being visited and watched while he worked on his own airplanes. He and his wife Rita came to my house and pre-inspected the Scout. It made all the difference to have him around.

On one occasion I was trying to figure out how a seatbelt, and maybe a shoulder belt, should be attached inside the framework. I went up to the aerodrome to consult with the master. Helpful as Cole usually was, I knew that he characteristically kept details very close to the vest, and I wondered what he might say about this.

"Tell me," I asked him, "how do you attach seatbelts to the framework?"

Out of deference to the famed Red Baron, Palen painted his Fokker triplane yellow—until his audiences demanded he do otherwise. Palen was especially dedicated to fostering an enthusiasm for aviation in what he called "young types" (bottom).

MIKE LOCKHART

"Well, people use different ways," was his answer.

"Like what, for instance?" I prodded.

"Well, they use modern belts, or original belts."

"Yes, but how do you fasten them?"

"You could bolt them in."

"Okay Cole, how do *you* do it?"

Cole laughed his great laugh and said, "Sometimes I've used rope." I laughed too, and decided to ask someone else about the seatbelts.

John Barker, antique airplane restoration expert

In 1977 Cole and I took his 1918 Nieuport 28 to New York City to promote a play. Towing a World War I aircraft to New York behind a pink 1959 Cadillac and then pushing it down Broadway was memorable enough, but the return trip is what sticks in my mind.

When the day was finally over, we packed the Nieuport on the trailer and loaded our gear. We needed some fuel for the Caddy so our last stop was a large discount filling station. Cole jumped out and told me to put some ballast on the front of the trailer. "Throw those two machine guns in the back seat on," he said; "they're perfect."

I got out and reached for one of the World War I-vintage Vickers guns. As I stood up with it in my arms I suddenly heard screams and yelling. Men and women were dropping gas hoses and running all over the place. I looked around to see what was causing the commotion. Then I realized what was happening. Sheepishly, I waved my hand

around to indicate they weren't about to witness a holdup.

The event left me wide-eyed, but to Cole, it was an everyday kind of occurrence. That was what made him so special. Working around Cole was an opportunity to get involved with history, aviation, action, obsessed people, weird deals, and one-in-a-million events, all piled into one.

Karl S. Schneide, curator, National Air and Space Museum

Cole Palen gave me my first airplane ride, in a 1918 Curtiss Jenny, when I was just five years old. Later, he taught me to drive in his 1914 Saxon motor car. My first experience with a motorcycle was riding double on his 1917 Harley Davidson. At 16, I spent every Sunday restoring and driving his 1918 Renault army tank. The ride I'll remember for a lifetime, however, came many years later, when Cole offered me a "great flying day" in his 1915 Nieuport 10—at the time, the oldest flying aircraft in the world.

Nearly 16 years have passed since I left the beloved aerodrome with a letter of recommendation from Cole to the director of the National Air and Space Museum. Now I'm the curator of the Museum's World War I aircraft. In 1986, I approached Cole to obtain his 1918 Nieuport 28 for our collection. The same aircraft that had been towed to New York by a Cadillac, the Nieuport was representative of the U.S. Army and Navy's first fighter and therefore a very important piece. Cole and I had long since established that he could not open the floodgates to other requests with an outright donation, so in exchange I offered him the 1915 Nieuport, a two-seat trainer less valuable to the Museum, but one I knew Cole wanted. He promised he'd have it flying the next summer.

Of course, he had the trainer ready to fly just as he said he would. The night before the flight, the anticipation kept me awake. At 5:30 a.m., I heard geese honking down at the airfield and knew Cole was getting ready. It was so cold that day that part of the preflight routine included polishing the frost off the fabric-covered wings. "Wing runners" pushed the aircraft to the middle of the runway and steered it into the wind. The Nieuport has no brakes or steerable tail wheel, so people must guide it to take off and catch it when it lands.

On the first swing of the propeller, the original Le Rhône engine burst into life. A few seconds later thumbs went up and the wheel chocks were pulled. As we bounced down the runway, I felt Cole's hand slowly letting go of the control stick. The aircraft was mine. At 500 feet the engine started to quit. Cole took over and after some fine-tuning we were flying again. We made gentle S-turns over the Hudson River, which was covered in fog.

It was starting to get very cold in the open cockpit, and the mixture of castor oil and gas spraying back from the engine was beginning to bother us. We headed back and began our descent, slowing the airplane with the usual procedure of cutting the ignition off and on. At 400 feet the Le Rhône gave up. The only sound heard at the aerodrome was the familiar howling laughter of Cole Palen, who shouted, "Hot dog!"

We braced ourselves for a dead stick landing as we approached the frosted dirt runway. The ancient French trainer bounced once and made a perfect landing—until we suddenly hit a rut on the field and spun around in a classic ground loop. As the aircraft came to a halt, Cole and I looked at each other. Without saying a word, we understood that experiences like this were what the work, the expense, and the devotion were all about.

STEPHANIE MAZE

Except for the colorful guy below, Palen had a knack for getting things with wings—like a 1931 trainer (above) and a 1911 Curtiss Pusher—into the air.

EARL HALL

EARL HALL

The BIG Balloon

How Project Echo taught NASA the value of a glitch.

by James R. Hansen

In the early hours of October 28, 1959, engineer Norman L. Crabill, who was spending the night in a NASA dormitory on Wallops Island, Virginia, was awakened by a night watchman. A long-distance telephone call was waiting for him in the front office. A reporter for a New York City newspaper wanted a statement "about the lights that you guys had put up." Crabill, an irascible young rocket engineer at the Langley Research Center's Pilotless Aircraft Research Division, had not even had time to celebrate his 33rd birthday properly the night before because of what had happened, and he was in no mood to explain the situation to some newspaper guy. "My statement is: 'It's three o'clock in the morning,' " growled Crabill, slamming the receiver down.

It was two years to the month after the sensational orbit of Sputnik 1, and just hours earlier people up and down the east coast of the United States had witnessed a brilliant show of little lights flashing in the sky. From New England to South Carolina, reports of extraordinary sightings came pouring in to police and fire departments, newspaper offices, and television and radio stations. What were those lights? More Sputniks? For ten minutes or so, it looked like a strange and distant fireworks display. Was it a meteor shower? UFOs? Something NASA finally managed to get into space? Or what?

Given what had really happened that evening, Crabill's an-

NASM

Ground inflation tests helped engineers identify potentially catastrophic problems with the Echo balloon. But test deployments in space proved the real key to Echo's success.

NASM

A technician works on the Echo I container (a backup is also visible). The charge that freed the balloon was placed inside the ring encircling the canister.

gry reaction to the reporter's queries was understandable. A disaster had taken place, one big enough to potentially damage the young engineer's career at NASA. The initial space deployment test of a 100-foot-diameter inflatable sphere for the agency's Echo I Passive Communication Satellite Project had ended abruptly, with the sphere blowing up as it inflated. As they floated back into Earth's atmosphere, the thousands of fragments of the aluminum-covered balloon had caught and reflected the light of the setting sun, creating the sensational flashing.

Out of the shreds of that test balloon, NASA eventually built a successful communications satellite program. After a fully operational Echo balloon was launched into orbit on August 12, 1960, the big silver "satelloon," as it was dubbed, continued to orbit Earth for eight years. During its long sojourn in space, Echo racked up a number of impressive accomplishments. First and foremost, by enabling numerous radio transmissions to be made between distant ground stations on Earth, it demonstrated the feasibility of a global communications system based on satellites. Beyond that, the long-term orbiting of the satelloon allowed scientists to accurately measure the density of the air in the far upper atmosphere. Moreover, Echo permitted scientists to demonstrate a triangulation technique for determining the distance between various points on Earth's surface, thus improving mapping precision. The satelloon also served as a test target for the alignment and calibration of a number of new radars. In addition, NASA researchers could study the long-term durability of the unique metallized plastic of the Echo balloons (an Echo II was launched in 1964) in order to evaluate similar materials proposed for components of other spacecraft, including early versions of a manned space station.

FREDERICK D. JONES/NASA LANGLEY

Perhaps the program's greatest achievement, however, was philosophical. Because its success blossomed out of no less than seven major launch or deployment failures, Project Echo bears powerful witness to the need for thorough developmental testing through all stages of a spaceflight program's evolution.

The official purpose of Project Echo's developmental flight-test program was "to ensure proper operation of the...payload package at simulated orbital insertion"—in other words, to see how well the folded Echo balloon would be ejected from its canister and inflated to shape in space. Deployment techniques had been developed for earlier U.S. passive communications satellites (especially for NASA's 1958 Beacon satellite and 1959 Sub-Satellite), but these were almost totally inapplicable to the giant Echo balloon. New schemes had to be perfected, and moreover, only some of the critical tests could be conducted on the ground; a vacuum chamber big enough to permit a complete simulation of the balloon inflating in the vacuum of space was impractical to build. The only option was to do the testing in the actual environment of space. NASA's plan, developed at the Langley center, was to flight-test suborbital launch vehicles from Wallops Island and then, launching from Cape Canaveral in Florida, try to get an Echo satellite in orbit.

Before risking a balloon in space, the Project Echo group decided to conduct a static inflation test on the ground to make sure that the balloon would take on a spherical shape and have the surface properties that would permit it to serve as a passive communications relay satellite between two distant ground stations. (Passive comsats serve simply as reflective surfaces for the bouncing of signals between stations.) Langley engineer Jesse Mitchell took a team of co-workers down to nearby Weeksville, North Carolina, on the north shore of the Albemarle Sound, where there stood a cavernous Navy blimp hangar that could easily contain the fully inflated Echo balloon. The inflation was slow, taking 12 hours or more, and thus did not come close to simulating the dynamics of the explosive inflation that would take place in space, but the results did reassure everyone that the balloon would work as a communication relay.

These tests also demonstrated that the original balloon, manufactured by General Mills, was seriously defective. When the balloon was inflated in the hangar, the triangular panels, or gores, began coming apart at the seams. Another manufacturer, the G.T. Scheldahl Company, had a glue just right for sealing the seams, so General Mills hired the company to construct a second sphere.

Though the ground testing proved critical, the only sure way to test the inflation process was to launch the sphere in

NASA LANGLEY

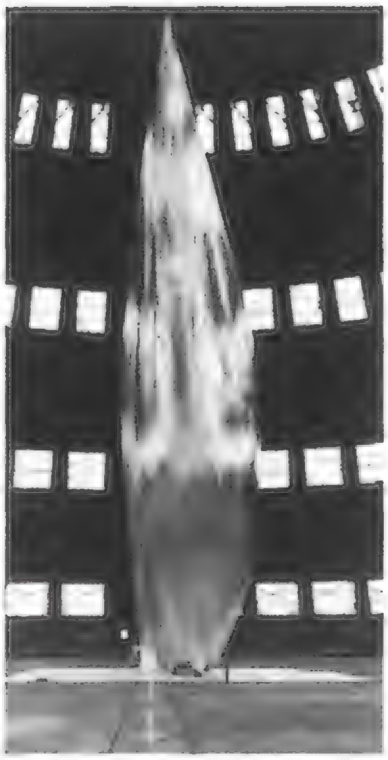
Edwin Kilgore (above, center), Norman Crabill (right), and an unidentified man take a peek inside the vast balloon. Today, Crabill (opposite, holding an Echo launcher model) believes NASA has forgotten Project Echo's most important lesson: space missions must include space deployment testing.

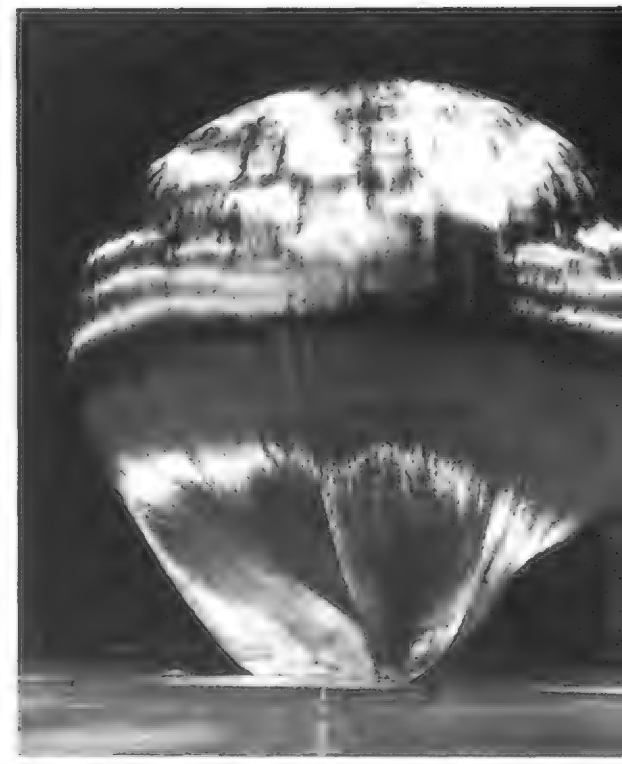
its container up to satellite altitude and see how it performed. To do this, Crabill and other members of the Langley task force designed a two-stage solid-propellant test rocket. The team dubbed the launcher Shotput; this, they thought, was the perfect nickname for a vehicle that would essentially hurl a big ball high out of the atmosphere.

Shotput's first stage was the Sargeant XM-33; its second stage, the ABL X248. The latter also served as the third stage of the Douglas Thor-Delta, soon to be one of the United States' primary satellite launchers. Though the test program's main purpose was to check out the Echo satelloon, testing this part of the Thor-Delta became a critical secondary task. The stage included a solid-propellant rocket motor designed to achieve proper satellite velocity and altitude. The motor was spin-stabilized, so after it had burned out and the motor-satellite complex had entered orbit, the whole ensemble had to be de-spun before the satellite could be separated. To accomplish that, engineers fashioned a weighted mechanism known as a "yo-yo," which stopped the spinning and allowed the container to separate safely.

The next step in the program was the infamous October 1959 launch of an actual full-scale balloon. For the first few minutes everything worked fine. The weather had been good, the winds not too bad. The booster, which had so worried everyone, performed flawlessly, taking the payload canister

NASA LANGLEY (6)





Testing Echo I's inflation (first four pictures) took a good half a day but proved worth the trouble: the trial confirmed the balloon's usefulness as a surface for the bouncing of radio signals. Many of the Echo I team brought their skills to Echo II (last two pictures; William J. O'Sullivan is the tall man at center in final picture, with Walter Bressette to his left).

up to second-stage burnout altitude. From there the payload separated from the booster, the canister opened, and the balloon started to inflate.

And then it exploded. In the weeks that followed, a team of Langley engineers worked hectically to determine the problem. A camera set up on the beach at Wallops Island had taken pictures of the balloon inflating and blowing up, but still it took the group several weeks to confirm the cause of the explosion. Shotput, which was engineer Norman Crabill's baby, had worked fine. But the balloon's inflation system turned out to be faulty. One of the inflating agents was water, contained in elastic containers within the sphere. Like other volatile liquids, water will boil explosively in the zero pressure of space. As William J. O'Sullivan, the father of the Echo balloon concept, later noted, it was "entirely conceivable that the elastic containers in which the water was carried inside the satellite might have leaked or ruptured during launch, and thus did not release the water at a slow and controlled rate as planned, to give a slow and gentle inflation." Instead, leaked water could easily have produced an explosion.

To ensure that the inflation system would not malfunction in the future, the team, led by Langley engineer Walter Bressette, switched to benzoic acid, a solid material that underwent sublimation—that is, transformation from a solid state directly to a vapor. With such a material, conversion to a gas would be limited by the rate at which it could absorb heat from the sun. In essence, it would "gas off" slowly, not instantaneously.

Another contributor to the explosion was residual air, which the payload engineers had intentionally left inside the folds of the balloon as an inflation agent. Langley's O'Sullivan once explained: "When the satelloon container is opened to release the satelloon in the hard vacuum of space, any air inside the folded satelloon or outside the satelloon between its folds tends to expand with explosive rapidity and rip the satelloon to pieces." To remove all residual air from future deployments, the engineers made over 300 little holes in the balloon, enabling air to escape after the balloon was folded.

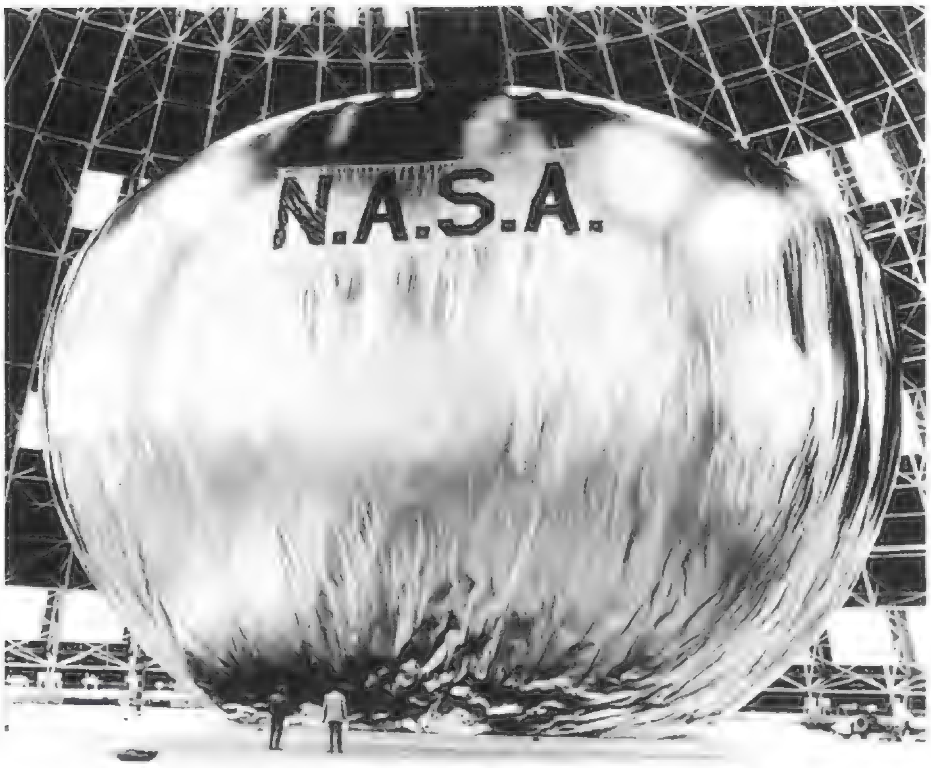
Once the balloon was packed, the canister was placed, slightly open, in a vacuum tank. When its internal pressure had been reduced to near zero, the canister was closed, with an O-ring maintaining the internal vacuum.

Finally, to better identify deployment problems, the engineers put a red fluorescent powder into the folded-up balloon. If the balloon ruptured during ejection or inflation in subsequent tests, the powder would blow out and leave a trail that could be instantly seen around the satellite even from Earth.

The second launch took place on January 16, 1960. This time, the yo-yo de-spin system did not deploy properly and the payload separated from the burned-out second stage still spinning at 250 rpm. When the red dye appeared in the sky, it was clear that the de-spin failure had caused the balloon to tear while inflating.

On the third shot, conducted five weeks later, the balloon tore and developed a hole, though not before Bell Labs was able to use the sphere to transmit voice signals from its headquarters in Holmdel, New Jersey, to Lincoln Labs in Round Hill, Massachusetts. A successful shot took place on April 1, but still the tests were incomplete, as the satellite did not yet carry any of the tracking beacons that the final version would have. (Because Echo's orbit would not be geostationary—hovering over the same spot on Earth 24 hours a day—such devices were required to enable ground crews to track the balloon.)

Nonetheless, the Langley group believed that it was ready for the next step: putting the completely equipped balloon on a Thor-Delta and going for launch. Unlike the Shotputs, which got the test balloons up to 200 to 250 miles, the much



more powerful Thor-Delta would ultimately take a real satelloon to an orbit some 1,000 miles above Earth. Even from there, the enormous Echo would be visible to people all around the world.

But this launch vehicle failed as well. The second stage refused to fire, and the whole rocket dropped into the Atlantic. The vehicle's manufacturer, Douglas, blamed a malfunctioning accelerometer.

By this point, the program had experienced a total of seven failures, including those with two small pre-Echo test satelloons. For a test conducted on May 31, the team went back one last time to the Shotput launcher. With tracking beacons aboard, the balloon deployed successfully, which helped the NASA engineers rally from their recent setback.

Still, critics continued to doubt the overall Echo concept. Some swore that even if the satelloon ever got up into space and inflated properly, micrometeorites would puncture its skin, destroying the balloon within hours. Not so, the Langley engineers countered. The idea was to pressurize the balloon just enough to overstress the material slightly, causing it to take on a permanent set. Thus, even after its internal pressure had dwindled to nothing, the balloon would retain its shape. And because the outer skin was not extremely rigid, it could be punctured by a small meteorite and still not shatter. Finally, a study by Walter Bressette showed that micrometeorites would erode less than one-millionth of the surface area a day. If only the launching and deployment would go right for once, the satelloon's sublimating-solid pressurization system would work long enough to enable engineers to conduct their communications experiments.

Finally, the next time around, it did go right. At 5:39 a.m. on August 12, 1960, Thor-Delta number 2 blasted into the sky from launch pad 17 at Cape Canaveral, taking its balloon into orbit. A few minutes later the balloon inflated perfectly. At 7:41 a.m., still on its first orbit, Echo I relayed its first message, reflecting a radio signal shot aloft from California to Bell Labs in New Jersey. "This is President Eisenhower speaking," the voice from space said. "This is one more significant step in the United States' program of space research and exploration being carried forward for peaceful purposes. The satellite balloon, which has reflected these words, may be used freely by any nation for similar experiments in its own interest." After the presidential message, NASA used the balloon to transmit two-way telephone conversations between the east and west coasts. Then a signal was transmitted from the United States to France and another was sent in the opposite direction. During the first two weeks, the strength of the signal bounced off Echo I remained within one decibel of Langley's theoretical calculation.

The newspapers sounded the trumpets of success: "U.S. Takes Big Jump in Space Race," "U.S. Orbits World's First Communications Satellite; Could Lead to New Marvels of Radio and TV Projection," "Bright Satellite Shines Tonight." So enthusiastic was the American public to get a glimpse of the balloon that NASA released daily schedules telling when and where the sphere could be seen overhead.

For the Langley engineers who were lucky enough to be at Cape Canaveral for the launch, this was a heady time. Norm Crabill remembers hearing the report that "Australia's got the beacon," meaning that the tracking station on that far-off continent had picked up the satellite's beacon signal. To this day, Crabill says, he "gets goose bumps just thinking about that moment."

Project Echo continued for several more years; in 1962, engineers staged "Big Shot," two space deployment tests of the Echo II balloon. The first was a disaster, with the balloon tearing apart because of a structural load problem. The second test was a success. Echo II was launched into orbit in 1964, serving, like its predecessor, as a passive communications relay.

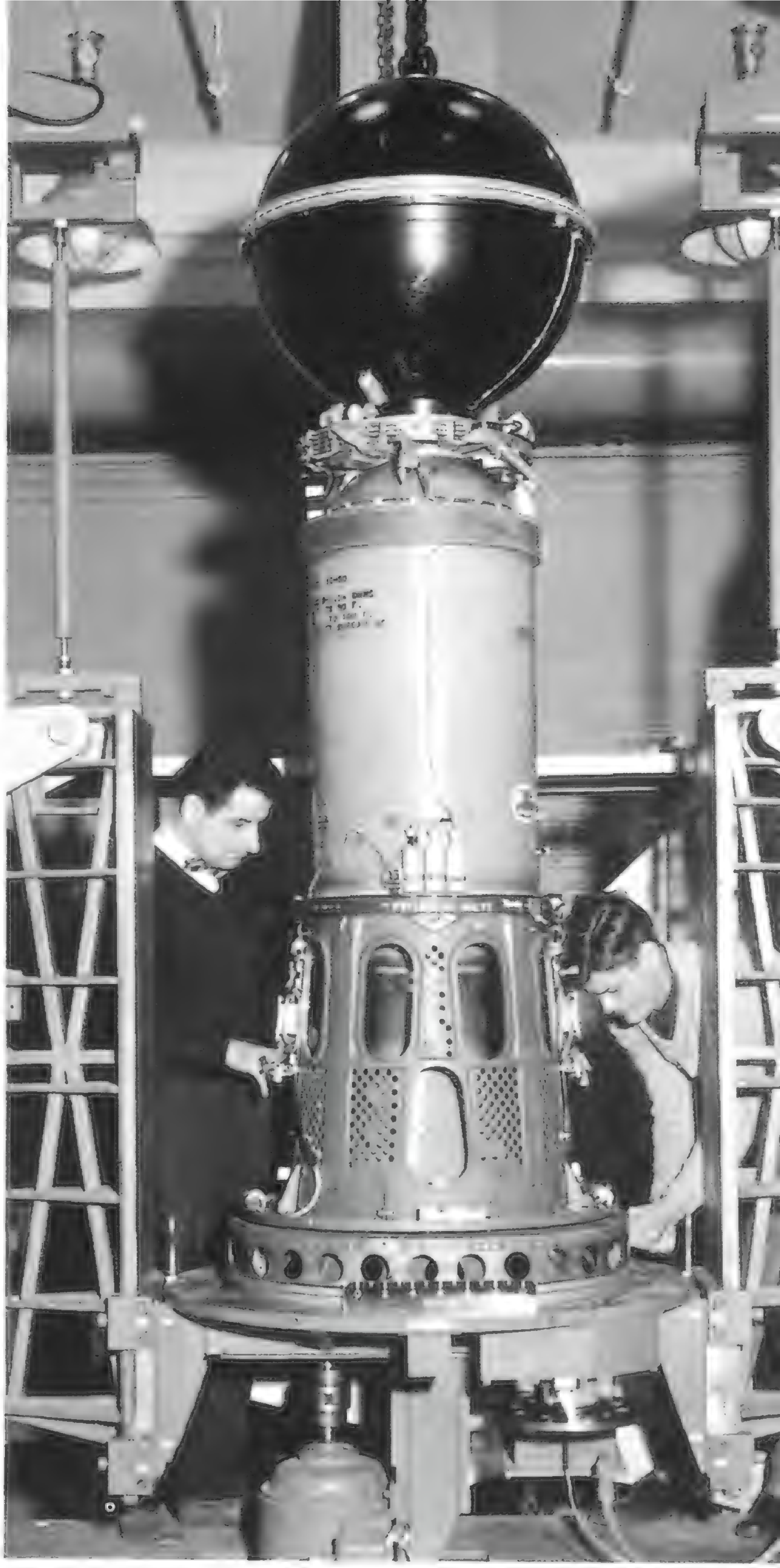
Pondering the course of Project Echo, one can't help wondering if today's NASA has forgotten the lessons of that undertaking. Do any of its current leaders even remember the effort? In the past few years the agency has suffered some significant failures while trying to deploy spacecraft. In April 1991 the Galileo spacecraft, a $1 billion-plus probe scheduled to begin exploring Jupiter in late 1995, was unable to

open its sensitive high-gain antenna and begin full operations. NASA has made repeated attempts to free the instrument, but none has yet worked. Then, in August 1992, a sophisticated electronic cable aboard the shuttle repeatedly balked during the attempted deployment of an Italian satellite known as the Tethered Satellite System. The snag spoiled a 12-year, $379 million science experiment.

Although the failures were unrelated technically, they may have something in common institutionally: neither deployment had ever been tested in space before the genuine article was launched. When asked about his reaction to the recent NASA failures, Echo veteran Norman Crabill exclaims, "My reaction is: Did NASA test it in space? No! Maybe we've forgotten something along the way to 'greater and better things.' You do your developmental testing; you do not shirk on it." For some projects, he adds, ground testing is enough, but with budgets growing tighter and so many NASA re-

Technicians prepare to spin-balance the final stage of the Shotput launch vehicle (right). The ABL X248 motor sits on the spin table; the balloon-containing canister is at the top. Once the Shotput was fully prepared for launch, a pencil-shaped shroud was fitted over the payload (below).

NASA LANGLEY (3)



During a test of the Echo II deployment, a structural load problem caused the balloon to explode. A camera aboard the launcher captured these images.

Echo: The Inside Story

Before the Echo program could undertake developmental flight-testing, the satelloon itself had to be refined. One preflight dilemma involved figuring out how to fit a 100-foot-diameter balloon into the 28-inch-diameter container that would be inserted into the launcher's nose. The technique that was eventually used evolved from a classic "Eureka" moment. One morning in 1960, Langley engineer Edwin C. Kilgore received a call from Scheldahl, the manufacturer of the Echo balloons. The company's technicians were having a terrible time: not only were they unable to fit the balloon into its canister, they couldn't even get the vast, bulky structure into a small room.

Kilgore mulled over the problem all day and part of the night, but it wasn't until the next morning that he happened upon a possible solution. "It was raining," he recalls, "and as I started to leave for work, my wife Ann arrived at the door to go out as I did. She had her plastic rainhat in her hand. It was folded in a long narrow strip and unfolded to a perfect hemisphere to fit the head." Recognizing the importance of his discovery, Kilgore told his wife that she "would have to use an umbrella or get wet because I needed that rainhat."

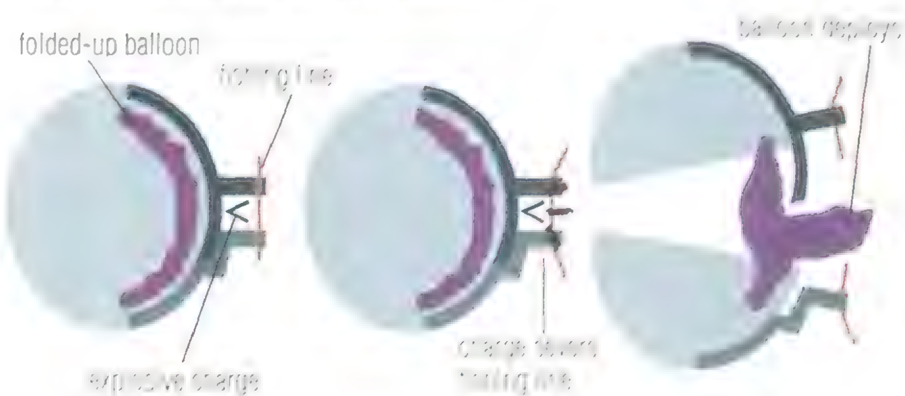
At Langley, Kilgore gave the hat to technician Austin McHatton, who had full-size models of the fold patterns constructed. Kilgore remembers that "remarkable improvement in folding resulted" almost immediately.

Another early problem the Echo engineers faced was designing a container that could release the satelloon safely and effectively. After several weeks, Langley engineers narrowed the field of ideas to five. Then they built models of these designs, plus 12-foot-diameter models of the Echo satellite. Finally, they constructed a spherical vacuum chamber with pressure-proof windows where they could study the dynamics of the container opening and the first two seconds of the satelloon's inflation. In order to observe and take pictures within the dark chamber, a special lighting rig had to be devised. Employing heavy bulbs enclosed in protective housings, the rig ensured that in the short time the test required, the bulbs would not overheat or be shattered by a shock wave.

The container-opening mechanism that eventually resulted from these tests was strikingly odd. To understand it, you first have to understand how the container itself was constructed. A sphere, it opened by parting at its equator into top and bottom hemispheres. The top half fit on the bottom much like a lid fits on a pot. The joint between the two hemispheres therefore formed a sort of vertically sliding valve. The halves had to move apart about an inch or two before the canister was actually open. It was in this joint that the charge was placed.

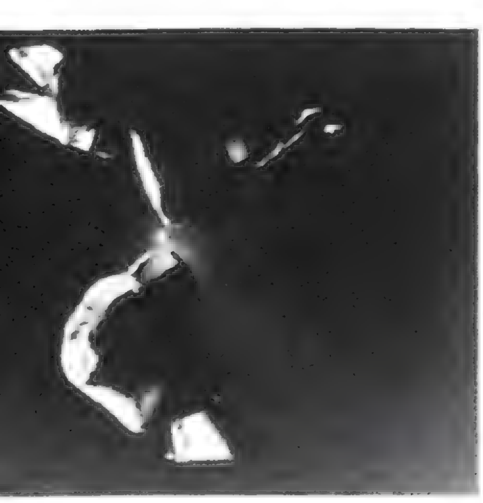
The charge was encased in a soft metal tube that encircled the canister; in cross-section, the tube had the shape of a sideways "V." (Picture what your belt would look like if you pinched the top and bottom edges toward each other.) This shape concentrated the blast into a thin jet that shot out the mouth of the "V." Once the charge was positioned, Langley technicians fastened the hemispheres of the container together. Because even the minimal pressure remaining inside the canister would be greater than that in space, the team had to take steps to prevent the canister from blowing apart too soon. The solution was to lace fishing line through eyelet holes in the hemispheres. When the explosive charge fired out, its jet cut the lacing so that the container halves were free to separate. At the same time, pressure from the charge drove the hemispheres apart, releasing the balloon.

Cross-Section of Echo Canister



sources being dedicated to the space station, Crabill fears that other space projects, especially those involving deployable structures, will be shortchanged of critical developmental testing.

"I'm not slighting the NASA guys who have worked on these recent projects," he continues. "They're some of the brightest people around. But you have to look at the bigger picture. It seems to me if you're going to commit to a Galileo probe or to a tethered satellite project, you need to commit some resources to doing the space tests. Put it on a shuttle and take it up and test the deployment of the antenna arrangement or the tether mechanism. Throw it up and let it work out. Yes, shuttle manifests are crowded and there are delays, but there are also other vehicles. There are problems. But so too is a non-functioning Galileo."



Even ground testing appears to be getting short shrift. Last August, the agency permanently lost contact with the Mars Observer probe during a fuel pressurization step. The process had never been attempted so late in a mission and in such a cold region of space. Investigators later theorized that both circumstances had conspired to produce a chemical reaction that ruptured the propulsion system and knocked the probe out of orbit. That disaster might have been avoided had the pressurization been simulated in a ground test.

Over 2,300 years ago, the most commonsensical of the Greek philosophers formulated an aphorism fundamental to the progress of the empirical sciences: "For the things we have to learn before we can do them, we learn only by doing them." That was the teaching of Aristotle, the first scientist, and that, according to Crabill and his colleagues, is the lesson of Project Echo.

The Wizard of 0g

I've never had any problem telling left from right, but occasionally I get confused with up and down. This happens when I am aboard NASA's KC-135, a reworked military tanker that produces periods of near-zero gravity by flying roller-coaster trajectories called parabolas. The reason I am there is to, as we scientists say, advance the forefront of science. Yet amid all the confusion of finding answers to the great questions of the universe, I find I have moments to conduct other, less serious scientific explorations—explorations that have earned me the nickname "the Wizard of 0g" (for "zero G," though it's pronounced "ahg").

My serious work, most of which involves studying the behavior of fluids in zero gravity, falls into the category of beautiful babies. That is, my experiments are beautiful and wonderful to me and maybe a half a dozen other techno-parents. But when I explain their finer details to a colleague outside this small circle, I see his eyes glaze over. Although he nods at the appropriate times and looks in my direction, his attention seems to be focused on some distant object—Andromeda perhaps.

My diversions in zero-gravity physics are different. Their appeal transcends the barrier of glazed eyes and head nods. In fact, I've found them so useful in teasing people into thinking about physics that I've turned them into the subject of classroom lectures.

These experiments fall into the category of "the Unfundables," meaning that no scientist worth his sodium chloride could obtain funding for them. Luckily, they really don't require any funding; one simply has to be there. Of the 40 to 60 parabolas on any one flight, a few always go unused. Experimenters on board often fritter away these dead periods by doing gymnastic maneuvers or Superman demonstrations. What I do is put a few diversions in my flight bag, and when my real work comes to a natural end or succumbs to Murphy's law (usually the latter), I pull them out and begin to really learn what the subtleties of zero gravity have to offer.

When compared to the magnitude of other forces we experience on Earth, gravity manifests itself as a rather small force. And you would think that the absence of such a small force could be readily accounted for when we go off into space and do experiments and build equipment (like zero-gravity toilets). The general lack of success in these endeavors (like zero-gravity toilets) is a tribute to our lack of intuition, the lack of a gut feeling for what happens when gravity is gone.

"Eggs," I say to the collection of kids around me while I hold up a couple of examples from my bag; "What could you do with eggs in zero gravity?" One kid, probably in the sixth grade, raises his hand and says, "You could eat them." "That's right," I say. "You could eat an egg in zero gravity." (I have to admit I hadn't thought of that one.) I spin the eggs on a table, where one quickly falls over while the other continues like a top. It's a familiar elementary physics demonstration, and they all know the explanation: the one that spins is hardboiled; the one that falls over, raw. It falls over because its liquid innards make it unstable. "Imagine that you are floating in zero gravity and do the same thing," I say to the kids, "only this time the eggs are not confined to the table top. What do you think will happen?" Only a few even come close (though the kids often do better at this question than my scientific colleagues).

So what *does* happen? Actually both eggs behave much as they do on Earth—just without the table top. The hardboiled egg continues to spin like a top, but the raw egg spins for only a moment before its axis of rotation changes and it tumbles end over end until I am (usually) lucky enough to catch it.

I am often asked to describe what zero gravity is like. This question falls in the realm of describing colors to a blind man. The closest description I can think of is this: If you have ever dreamed about flying, about simply spreading your arms and floating away, that is what zero gravity is like.

When choosing a likely diversion for zero gravity, one must first determine if gravity has any effect on its behavior. The diversion that first captured my imagination was the yo-yo. Yo-yos have been companions of mine since childhood. One of my favorite tricks is "walking the dog," in which you allow the spinning yo-yo to contact the floor, making it roll off, seemingly on the end of a leash. Imagine, I thought, doing this in zero gravity! I could have the yo-yo roll across the ceiling, a trick impossible to do on Earth—"the fly walk." Unfortunately, my zero-gravity intuition was lacking:

nothing of the kind was possible.

In zero gravity, the yo-yo refuses to sleep. Sleeping (on Earth) is when the yo-yo comes to the end of its string and sits there spinning away until called back by a twitch of the finger. In zero gravity, however, the yo-yo reaches the end of its string and immediately returns. This is because a sleeping yo-yo requires a taut string; in the absence of gravity, once the string of a yo-yo is reeled out, it immediately grows slack. The implications of this depressing discovery are that nearly every real jaw-dropping, ogle-producing, "I can't believe you can do that with a yo-yo" trick is impossible in zero gravity. This reality of nature is as devastating to a yo-yoist as the discovery of early aviators that one cannot fly by flapping wings strapped to one's arms.

But, like the early aviators who learned to modify their approach to flying, I discovered that a host of amazing tricks are possible in zero gravity if one simply takes advantage of the special traits of that environment.

Perhaps the most important discovery I made by yo-yoing is why our zero-gravity intuition is so poor. This problem stems from the difference between velocity and acceleration. Aristotle deduced that a constant force applied to an object resulted in constant velocity. It was not until Newton came into the picture that we learned that a constant force resulted instead in an acceleration. Aristotle got it wrong because he based his observations on an environment where frictional forces were significant. Most of the world around us is dominated by frictional forces; thus, Aristotle was only generalizing from what his intuition told him. It took exceptional observations by Newton to get the story right. In zero gravity we are in a domain where frictional forces are nearly absent; hence, our intuition, fine-tuned by a world with friction, is unreliable.

I ask the students around me, "Move your hands with a constant velocity." Everyone does as I say. Then I ask, "Now move your hands with constant acceleration." They give me this look like "You gotta be kidding," then various appendages begin to flail like a herd of panicked animals. Acceleration, although omnipresent, is so foreign to us that few have developed a feeling for the concept, yet everyone has some intuition about velocity ("Really officer, I was only going 55"). When I move an object in zero gravity, say a cup filled with screws, my natural choice is constant velocity; thus, there is no resulting force on the screws and they float out of the cup and all over the cabin. Only when I move the cup with constant acceleration will the screws stay put. Yo-yoing in zero gravity has taught me how to move my hands with constant acceleration, thereby applying force to the object in hand.

Aboard the KC-135, each blissful, 30-second period of zero gravity is followed by nearly a minute of two Gs. Effectively, I weigh 330 pounds. Bullets of sweat do not just roll down one's forehead, they stream across—like raindrops on the windshield of a car. Your head is heavy, your cheeks sag, and your eardrums rumble. You develop this uneasy feeling in your stomach while your mouth profusely salivates. You listen for the subtle change in engine pitch that lets you know this will all soon come to an end.

Sometimes during the two-G period, one of those little foam plugs I wear in my ear will suddenly pop out, creating an auditory effect similar to when the mute button is toggled off during one of those loud, obnoxious TV commercials. Once when this happened, I couldn't chase down the plug because the airplane was about to enter the next zero-gravity phase and I had been preparing for what has so far turned out to be my favorite "diversion."

As soon as we were weightless again, I squeezed a bicycle water bottle until an orange-sized blob of water was bobbing in front of me. Then I inserted an Alka-Seltzer tablet into the blob and observed what future space colonists will undoubtedly see as their salvation to zero-gravity heartburn.

Before that flight, I had devised theories about what I thought would happen, which I later shared with a group of students. My first theory was that bubbles would form at the surface of the tablet and remain there rather than floating off, since gravity-driven buoyancy is absent. I then assumed that the bubbles would coalesce and form a gas pocket surrounding the tablet, preventing more water from reaching the surface and stopping the fizz reaction. I called this theory the Gas Film Quench, or (in scientific tradition) the GFQ.

DAVID CLARK (2)

My second theory was that bubbles would form at the surface but not coalesce. Instead, they would form a bubbly mass that allowed water to continuously seep to the tablet and generate a new layer of bubbles that pushed the previous layer outward. At first I called this the Spit Bug Nest model (SBN), but I found that few could identify with spit bugs, so I changed the name to EBH, for the Expanding Beer Head.

As it turns out, neither idea was correct. And when I asked the students to formulate their own theories, they didn't fare much better. (They did exhibit a flair for naming their theories: Exploding Pepperoni Pizza, or EPP, is a favorite.)

The bubbles *do* float away from the tablet, not because of a gravity-induced buoyancy but because the chemical reaction between the tablet and the water creates an imbalance in pressure and pushes them away. Actually, the most critical factor in determining what ultimately happens turns out to be the size of the blob of water. If it is about plum-sized or smaller, the bubbles have sufficient velocity to reach the surface of the blob and pop. The tablet dissolves much as one does on Earth—with the added feature of doing so without being contained in a glass.

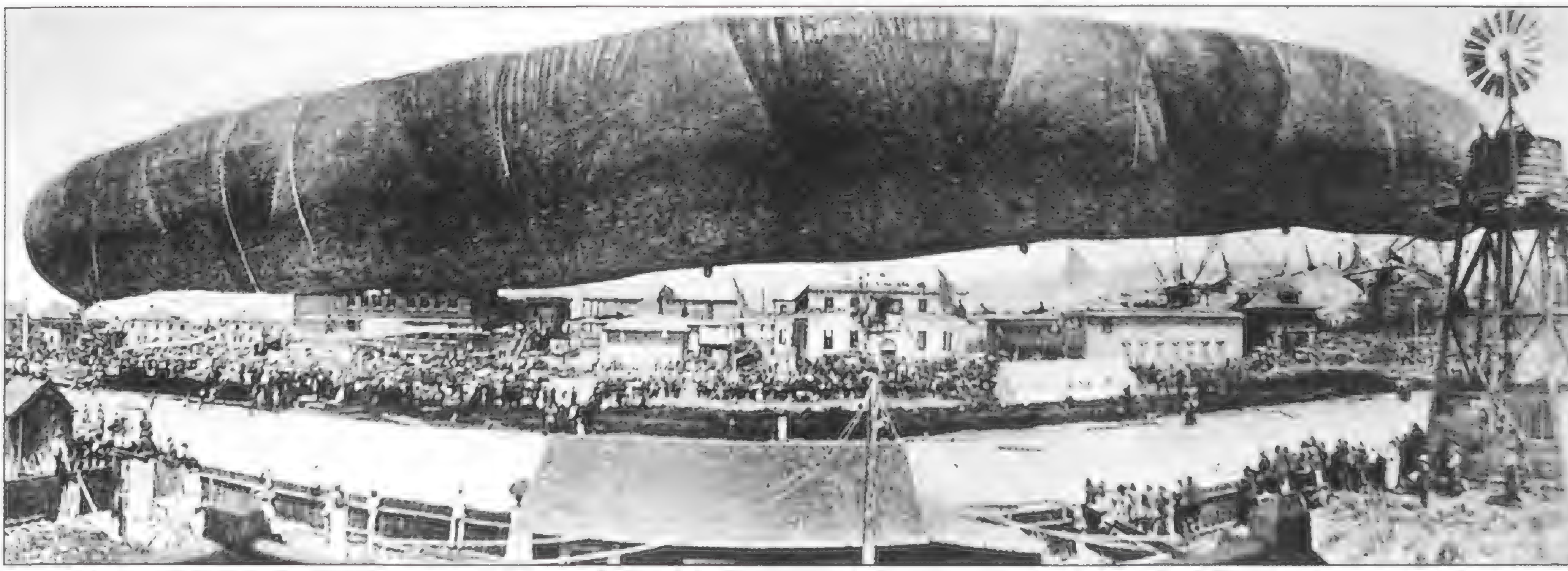
However, in a larger blob, such as the orange-sized one I first experimented with, the bubbles aren't able to reach the surface. As they move outward from the tablet, they bump into each other and coalesce, forming gas pockets that make the entire blob quake and quiver, until gravity returns and slaps it to the floor.

All too soon, a week of flights comes and goes. The last flight unfolds much the same as those of the previous days, except that after the KC-135 rolls to a stop and the whine of the engines dies out, we scramble to unbolt our equipment, pull up what seems like miles of duct tape, and off-load everything onto the waiting forklift. Then we're off on a hectic drive to the airport.

As usual, I make my flight with minutes to spare. I walk on, stick my head into the cockpit, and ask the captain if he can liven up the flight home by pulling a few parabolas. Then I collapse into my seat, feeling more like a tired scientist than a wizard.

—Don Pettit

Lead Zeppelin



BERKELEY HISTORICAL SOCIETY (2)

It was to be a quarter of a mile long and carry 500 passengers from San Francisco to New York in a single day. Eager investors contributed $40,000, and in 1908 a prototype of the Morrell airship actually flew—briefly.

No one seemed to mind that the National Airship Company of San Francisco had been incorporated under the somewhat less rigorous statutes of South Dakota. Nor was anyone overly concerned with the background of John A. Morrell, founder and company president, who was rumored to be an ex-streetcar motorman from Chicago. Not only had he never built an airship—he had never even flown in one.

What did matter to the prudent investor of 1907 was that the airship obviously held the key to the future of aerial transportation and Morrell was offering a chance to get in on the ground floor for 25 cents a share.

Morrell had chosen wisely in bringing his visionary if slightly unfocused plans to San Francisco. The city was the site of the first American powered aerial machine flight: in 1869 Frederick Marriott had led his steam-driven dirigible around on the end of a rope for 10 minutes. In 1903 another San Franciscan, August Greth, flew his 75-foot-long airship over the

The failure of John Morrell's 1908 prototype airship proved, if nothing else, the old saw about "the harder they fall."

business district before it fell into the bay off Presidio Point.

By far the most successful of all the early American aeronauts was from nearby Oakland. Thomas Scott Baldwin's *California Arrow* was the first reliable U.S. airship. It won all flying prizes at the 1904 St. Louis World's Fair.

By 1907, however, the focus of aeronautical attention was centered on Europe, where Count Ferdinand von Zeppelin astounded the world with his huge rigid eponymous airships. His third ship, the LZ-3, achieved the remarkable speed of nearly 30 mph and remained aloft for eight hours with half a dozen crewmen aboard.

Count Zeppelin's achievements were front-page news around the world. When John Morrell promised ships that far exceeded the Zeppelins in size, speed, range, and capacity, he inspired people to believe that American ingenuity was about to take the lead. And Morrell could not be accused of copying the count's ideas. The Morrell airship would be an original.

The Zeppelin was actually a row of balloons enclosed in a rigid aluminum frame. The motors were carried in gondolas beneath the hull, which was covered with fabric to give the ship its smooth shape. Morrell's design would dispense with the frame and separate gas compartments. His ship would consist of a enormous muslin gasbag with the engines and passenger compartment suspended underneath by ropes.

Zeppelin's latest ship was 420 feet long; Morrell's would be 1,300. The Zeppelin could carry at most a dozen people at a top speed of 27 mph. Morrell's ship would be able to span nearly 3,000 miles in 24 hours with 500 passengers. In addition, Morrell's prospectus promised that the passenger chairs would weigh just 17 ounces and the beds, their mattresses inflated with a "secret lifting gas," would weigh a mere 27 ounces.

Morrell wisely decided to begin with a 300-foot prototype. Construction was swift; the gasbag was completed in Berkeley in February 1908. But when the bag was filled with some 300,000 cubic feet of "illuminating gas" it could barely lift its own weight. It was not buoyant enough to lift engines, fuel, or passengers. As Morrell was pondering this unexpected result, a sudden wind tore the big bag out

of the hands of the ground crew and blew it 20 miles across the bay to Burlingame.

Undaunted, Morrell began work on a bigger bag. At 485 feet, this one would hold more than enough gas to get itself and its crew airborne. It was ready for testing in just three months.

The first flight was scheduled for Saturday, May 23, 1908, at the corner of Grove and Kittridge in Berkeley. Several thousand people, many of them investors, were on hand. Nearly a half-million cubic feet of coal gas, borrowed from the supply generated for Berkeley's streetlights, was used to inflate the enormous bag, which struggled to rise against the restraining grasp of hundreds of volunteers.

A walkway for the crew was suspended on stout ropes 20 feet beneath the gasbag. Consisting of canvas mattresses connected by nets of rope, it ran nearly the full length of the ship. Five 40-horsepower auto engines, spaced along the walkway, powered the ship. Each engine drove two propellers mounted on brackets on either side of the walkway.

Nineteen men climbed aboard. In addition to Morrell, the crew included eight engineers, five valve tenders, four photographers, and a pilot. At the last minute an additional crew member declined to participate. George H. Loose, the ship's builder, later claimed that Morrell had disregarded his advice during construction and that the ship was unsafe.

Loose's defection had little effect on Morrell's enthusiasm. "Our fortunes are made," he told a reporter as he climbed aboard. "We'll all go to Europe and surprise them. This is the day we astound the world. We'll leave Berkeley in the morning and eat dinner in Portland tonight."

Satisfied that his crew mates were at their stations and all was ready, Morrell gave the signal to cast off. A mighty cheer from the crowd prevented ground crew at the bow from hearing the order. The stern had risen more than 100 feet and the hull was standing on its nose at a 45-degree angle before the men at the bow realized the rest of the ship had taken off. They released their lines and the crooked airship slowly rose to nearly 300 feet. A *San Francisco Chronicle* reporter later described the scene: "When the balloon soared skyward the enthusiastic throng burst into prolonged cheering, and the shrill cries of the excited children and women were ringing in the ears of the ill-fated aeronauts when their machine broke in half and spilled them back to earth. In fact, shrieks of ecstasy were oddly mingled in one moment with the screams of those who first saw the accident and realized the terror of the swiftly approaching catastrophe.

"The forward portion of the airship withered into flopping cloth as it lost buoyancy, and, as this happened, it began to descend with frightful velocity. In an incredibly brief space of time the whole machine dropped to earth, flapping [to] the ground with its helpless wreckage like a crippled bird fluttering in its death agony. Pinioned in their seats in the machinery and tangled in the mass of network which enveloped the whole apparatus, the crew and passengers were piled into one sickening heap, as helpless as doomed rats in a cage."

Thirteen of the 19 men aboard were injured, none fatally. Morrell broke his right leg.

Loose, the ship's builder, said that it had proved impossible to fill the unsupported envelope with enough gas to keep it rigid. As soon as enough pressure built up to make the bag firm, the emergency valves would open. Sealing the valves was out of the question: that could have caused the fabric to burst.

From his hospital bed Morrell acknowledged that his plans had suffered a slight setback. He blamed stockholders for forcing him to undertake a premature ascent before certain aerodynamic principles had been completely worked out. His enthusiasm, however, remained undiminished. "The scoffers will yet see the day when the Morrell airship will successfully navigate the heavens," he declared as he outlined his next creation. It would be 750 feet long, powered by eight engines, and cruise at a top speed of 100 mph. But this gasbag would have two layers of silk interwoven with "flexible aluminum." The bag would be divided into more than 100 compartments to prevent all the gas from escaping from a single hole. Fortunately for Morrell, the ship was never built and he was able to retire from the airship business with nothing more serious than a broken leg and a bruised ego.

—Lee Payne

A crowd of 6,000 turned out in Berkeley for the airship's first flight, which was high entertainment indeed.

From Flagstaff to Fra Mauro

To a Rocky Moon: A Geologist's History of Lunar Exploration *by Don E. Wilhelms. University of Arizona Press, 1993. 477 pp., $29.95 (hardcover), $19.95 (paperback).*

NASA/JOHNSON

Apollo 15 astronaut Dave Scott pauses at a scenic overlook at the edge of Hadley Rille.

Although the Apollo program was largely driven by politics and technology, landing on the moon was also a quest for a deeper understanding of our solar system. No one is better suited to tell the story from this perspective than Don Wilhelms, who was intimately involved in the process of Apollo lunar science from the earliest stages. His gift for geology (the "profoundly historical science") and his love for astronomy serve him well in recounting the history of lunar geological investigations in *To a Rocky Moon.*

Wilhelms begins his story with lunar and cratering studies that date back to the turn of the century. He describes the early mapping programs of the U.S. Geological Survey in Menlo Park, California, and Flagstaff, Arizona, the selection of the Lunar Orbiter targets and Apollo landing sites, the geological training of the astronauts, and the six Apollo landings and their scientific results. Along the way, he provides insight into the process by which geologists deciphered the history of the moon, first without any field work or samples, and later with only limited excursions.

Wilhelms has put together a thoroughly readable account that, if not for the casual reader, should nonetheless appeal to a broad audience of those interested in the history of science or geology. *To a Rocky Moon* is a history not only of scientific investigation but also of the people who learned to read the story written in the moon's surface. The tale that unfolded before them was one of great drama, involving cataclysmic impacts, meteoroid bombardment, and flowing lava. What they learned also sheds light on Earth's history, which is better understood by understanding the moon.

In recalling the end of the Apollo era, Wilhelms quotes former Chief Justice Earl Warren, who described the program as an "expedition of the mind, not of the heart." It's obvious from this book, however, that Wilhelms' work to understand the mysteries of the moon has been a journey of both.

—Priscilla Strain is the curator of the lunar sample collection at the National Air and Space Museum and co-author (with Frederick Engle) of Looking at Earth.

Still Missing: Amelia Earhart and the Search for Modern Feminism *by Susan Ware. Norton, 1993. 304 pp., $22.00 (hardcover).*

"I chose to fly the Atlantic because I wanted to," Amelia Earhart wrote in *The Fun of It,* a 1932 book about her history-making feats of aviation that year and in 1928. "It was, in a measure, a self-justification—a proving to me, and to anyone else interested, that a woman with adequate experience could do it."

That simple credo, which effortlessly mingles Earhart's own drive for adventure and fulfillment with her public-minded concern for other women's aspirations, encapsulates the twin themes of historian Susan Ware's biography. Earhart's life has been chronicled many times, but *Still Missing* is the first effort that puts the aviator and her career into the history of women's advances in this century. Earhart was part of a generation of strong, publicly successful women born around 1900, contemporaries of the flapper but nowhere near as well remembered. They included path-breaking women like sports

star Mildred "Babe" Didrickson and photojournalist Margaret Bourke-White, as well as Earhart. Earhart's own flight instructor was a woman; so was the wealthy Philadelphian who financed the flight in which Earhart made her famous first Atlantic crossing (as a passenger). Unlike the preceding generation of suffragists, these women combined careers and acclaim with marriages that were, at least for the time, egalitarian, and looked ahead to the future with an optimism about women's rights that proved (at best) premature.

Ware traces the changes in Earhart's image through publicity portraits and newsreels as her fame grew, as well as the enthusiasm with which a pre-Depression America accepted in her "a highly individualistic yet compelling new way to be a woman." Awed schoolgirls and college students flocked to her lectures and newspapers wondered what to call her after she married her publicist-manager, George B. Putnam.

Ware writes that she wanted to "rescue Amelia from the cult of her disappearance," to replace an impossibly romanticized, martyred enigma with a useful piece of history. Grown-up women of today, aviators and others, should find this Earhart a more plausible and heartening forerunner.

—Amy E. Schwartz writes for the Washington Post.

COMPUTER SOFTWARE

Flight and space simulation software continues to multiply: users can fly against the Red Baron, run an airline, or plan a trip to the moon—all while sitting in front of a computer screen. IBM-DOS is still the most common format, but Macintosh is increasingly popular. The latest trend is playing against other users on networked computers or services. The available and soon-to-be-available software in the following list varies in sophistication, realism, and price. For more information, visit your local computer software dealer.

Civilian and commercial flight *Flight Simulator 5.0* (Microsoft); *Aircraft and Adventure Factory* (Mallard); *Chuck Yeager's Advanced Flight Trainer* (Electronic Arts); *Stunt Island* (Disney); *Air Bucks—Build and Run Your Own Airline* (Impressions); and *Air Traffic Control* (HJC).

World War I *Knights of the Sky* and *The Ancient Art of War in the Skies* (Microprose) and *Red Baron* (Dynamix).

World War II *Aces of the Pacific* and *Aces over Europe* (Dynamix); *B-17 Flying Fortress* and *1942—The Pacific Air War* (Microprose); *Battle of Britain* and *Bomber* (Deadly Games); *Air Combat Classics* (LucasArts); *Pacific Strike* (Origin); *WW2 Air Force Commander* (Impressions); and *Hellcats* (Graphic).

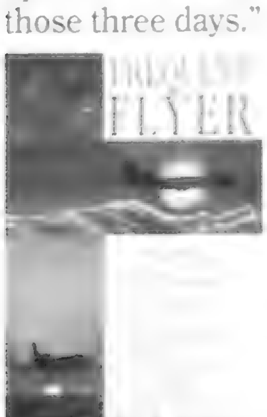
Modern combat *F-14 Fleet Defender, F-15 Strike Eagle, Nighthawk F-117A Stealth Fighter, Jump Jet,* and *ATAC—The Secret War Against Drugs* (Microprose); *Falcon, MiG-29, Tornado,* and *F-18* (Spectrum Holobyte); *F/A-18 Hornet* (Graphic); *Chuck Yeager's Air Combat Trainer* (EA); *AV-8B Harrier* (Domark); *A-10 Tank Killer* (Dynamix); *Air Warrior* (Kesmai); *Megafortress* (Three Sixty); *Strike Commander* (Origin); *Jet Fighter 2* (Velocity); and *Flight Commander* (Big Time).

Helicopters *Comanche Maximum Overkill* (Nova Logic); *Gunship 2000* (Microprose); and *Valkyrie* (GameTek).

Space *Shuttle* (Virgin); *Space Shuttle* (Software Toolworks); *Americans in Space* (Multicom); *Buzz Aldrin's Race Into Space* (Interplay); *Lunar Command* (Mallard); *SpaceMax—Space Station Construction* (Final Frontier); *Space Adventure* (Knowledge Adventure); *Orbiter* (Spectrum Holobyte); *Orbital Mech* (Studio Zero); *X-Wing* (LucasArts); *Space Quest* (Sierra); *Orbits* (Software Marketing Corporation); *SimEarth* (Maxis); *Expert Astronomer* (Expert); and *Discover Space* and *Where in Space is Carmen Sandiego?* (Broderbund).

Frequent Flyer: One Plane, One Passenger, and the Spectacular Feat of Commercial Flight *by Bob Reiss. Simon & Schuster, 1994. 318 pp., $23.00 (hardcover).*

The premise is simple: follow one airliner during 72 hours of standard nonstop operations and absorb the wonders of commercial air travel in the process. As the press release accompanying the book puts it, "Nothing that has ever effected [*sic*] commercial aviation has not, in some way, contributed to the successful operation of ship 714, before or during those three days." Well, maybe.



Author Reiss seems bedazzled by it all, like a kid on his first visit to a fire station gazing at the big shiny trucks and the pole that the firemen slide down when the bell rings. Sometimes the gushiness is just a little too much. From all the exclamations, you'd think pilots shout their way through checklists: Gear! *Check!* Flaps! *Check!*

This is not the place to get a definitive course in aviation, but then that's not the intent. What we have here is an innocent act, a writer who says his near brush with disaster—a Swissair jet he was on lost an engine outbound from New York—made him think about airlines and airliners. In recounting his sojourn with number 714, one of Delta Airline's Lockheed L-1011 TriStars, he interweaves a little history and some descriptions of ground support troops like dispatchers and safety investigators. Almost everyone at Delta is as well behaved as schoolchildren on the day the president visits.

So resist nit-picking the explication and instead enjoy finding out about the cockpit jokes (yes, they are occasionally vulgar) and the catty gossip about what Delta did to Zsa Zsa Gabor when she insisted on releasing two pet dogs from their containers into the cabin. Reiss has a knack for getting people to talk, and although some of the conversations aren't worth recording, he manages to pry some gems from pilots and airline staff. When he interviews mechanic Jimmy Martin about a long-since-repaired wing spar crack on number 714, a reluctant Martin ("Are we allowed to talk like this?" he wonders to a colleague) explains that the well-documented crack had occurred in the air, and that when he had worked on the repair, the crack was so big "I could stick my head through it." The incident resulted in an inspection of the entire TriStar fleet, Reiss reports.

But the author comes away from the whole experience reassured that flying is safe. Somehow, you had the feeling it would turn out that way from page one.

—George C. Larson is the editor of Air & Space/Smithsonian.

BRIEFLY NOTED

Swing Wings: Tornados, Tomcats and Backfires *by Tim Laming. Osprey (available from Motorbooks International), 1993. 128 pp., color photos, $15.95 (paperback).*

Model builders craving details of variable-geometry jet fighters and attack aircraft will find a gold mine in this presentation of Tim Laming's tack-sharp photographs. The aircraft are portrayed in their natural state—peeling paint, wear and tear—but somehow that adds to the appeal, particularly in the sequence of Tornados photographed during Desert Storm. The text, by Laming, is stream-of-consciousness descriptions of hardware.

—George C. Larson

The First Team and the Guadalcanal Campaign: Naval Fighter Combat From August to November 1942 *by John B. Lundstrom. Naval Institute Press, 1993. 600 pp., b&w photos, $44.95 (hardcover).*

Conventional wisdom holds that U.S. warplanes in 1941-1942 were no match for Japan's nimble, long-range, cannon-equipped Mitsubishi A6M Zero. Nevertheless, John Lundstrom ably demonstrates in *The First Team and the Guadalcanal Campaign* that the first year of the Pacific war actually ended in a draw between the Zero and the Grumman F4F Wildcat. His research proves that from December 1941 to November 1942, U.S. Navy carrier pilots shot down 40 Zeros while losing 41 Wildcats in air-to-air combat (those are actual results, not the inflated figures beloved by military aviation buffs).

Over-claiming was rampant in the southwest Pacific and elsewhere. Lundstrom concludes that the "First Team"—as U.S. Navy carrier pilots referred to themselves—claimed two Japanese airplanes for each one actually destroyed. (For their part, the Zero pilots claimed six American airplanes for every one shot down.) Lundstrom attributes the

First Team's respectable record to the inventive tactics of American pilots, their training in deflection shooting, and the Wildcat's sturdy construction.

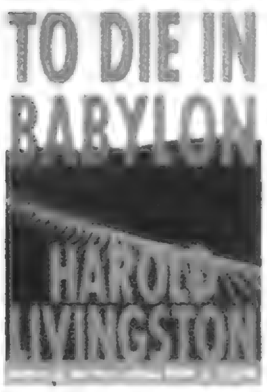
The book contains an abundance of photographs and line drawings. Though at times I needed an atlas to know where Lundstrom was taking me, this is a magnificent piece of aviation history and well worth the considerable effort it demands of the reader.

—Daniel Ford wrote Flying Tigers: Claire Chennault and the American Volunteer Group, *one of the first books to reconstruct Pacific air combat from both sides.*

To Die in Babylon *by Harold Livingston. St. Martin's Press, 1993. 419 pp., $21.95 (hardcover).*

Like so many war novels, *To Die in Babylon* is constructed around the convergence of widely separated lives brought together by a conflict. In this case, it is the Gulf war. Indeed, the publisher calls this "the first great novel" of that war.

The plot revolves around four main players: an F-16 jock, a beautiful blonde television news anchor, a major in the Iraqi Republican Guard, and a female U.S. Army helicopter pilot. Though they often serve as crash dummies for the plot, Livingston moves his characters around with considerable skill. They are also often an improvement on reality: Livingston's television news anchor, for example, is a stunningly tricked out Peter Arnett. It works: nobody will put the book away half-read.



The depiction of war carries the sound of real experience. Livingston is a longtime fighter pilot, and the combat aviation scenes have an easy authority. To add some critical mass to a regional war, Livingston mixes in Israelis—he flew for them in 1948, and his knowledge of the territory shines through.

Interestingly, Livingston is at his best re-creating life on the Iraqi side. Perhaps for the first time, the Allied campaign is portrayed as a high-tech juggernaut rolling over a weaker Third World enemy. In fact, the lesson of *To Die in Babylon* may be that when the great novel about this yet unresolved war finally appears, it will not be about the shooters or the barrel. It will be about the fish.

—Carl A. Posey is an editor at Time-Life Books in Alexandria, Virginia.

CREDITS

The Search for the Challenger. Glenn Arnett is a Naval Reserve diver who lives in St. Augustine, Florida.

Sandbagged. Bob Henson, a writer-editor at the University Corporation for Atmospheric Research in Boulder, Colorado, is the author of *Television Weathercasting: A History.*

How the Skunk Works Works. William E. Burrows is the author of *Deep Black* and co-author of *Critical Mass: The Dangerous Race for Superweapons in a Fragmenting World.*

Further reading: *Lockheed's Skunk Works: The First Fifty Years*, Jay Miller, Aerofax, 1993.

"Aircraft of the Skunk Works" graphic supplement. John Batchelor's art has appeared in publications all over the world and in more than 100 volumes of Time-Life books.

A Hole in the Stars. Having survived his first effort at book writing, Andrew Chaikin looks forward to songwriting.

You Can Look But You Can't Touch. Syndicated columnist Fred Reed is a contributing editor of *Air & Space/ Smithsonian.* His next adventure will take him on a Bosnian relief flight with the U.S. Air Force.

Seattle-based photographer Dan Lamont first covered Boeing aircraft for a class project when he was a fourth grader.

Mars Direct. Lance Frazer is a writer specializing in science and technology. He would volunteer for a berth on Mars Direct as long as there's an Earth Direct ride at the other end.

Further reading: *Mars Beckons*, John Noble Wilford, Alfred A. Knopf, 1990.

That Magnificent Man and His Flying Machines. Further reading: *The Old Rhinebeck Aerodrome*, E. Gordon Bainbridge, Exhibition Press, 1977.

The Old Rhinebeck Aerodrome will remain open despite the death of Cole Palen. For information about the 1994 season, call the aerodrome at (914) 758-8610.

The Big Balloon. James R. Hansen is the chairman of the history department at Auburn University in Alabama. He is the author of *Engineer in Charge: A History of the Langley Aeronautical Laboratory, 1917–1958* (NASA, 1987).

The Wizard of Og. A staff scientist at Los Alamos National Laboratory, Don Pettit is currently contributing to the redesign of the space station.

Lead Zeppelin. Lee Payne is the author of *Lighter Than Air, An Illustrated History of the Airship.*

A New Life for an Old Carrier. Phil Scott is the author of *American Icarus*, which will be published by Addison-Wesley next year.

CALENDAR

April 9
Flying Companion Seminar. Sponsored by the Ninety-Nines, Inc. San Jose State University, Department of Aviation, San Jose, CA, (408) 264-0229.

April 23 & 24
Annual Museum Showcase & WalkAbout. Lone Star Flight Museum, Galveston, TX, (409) 740-7722.

May 12–15
"The First War in the Air: Eighty Years On," joint meeting of the League of WWI Aviation Historians and the Canadian Aviation Historical Society. Ottawa, Ontario, Canada, (613) 996-7469.

May 12–17
9th Air Force Association 1994 Convention, May 12–15, followed by conference, "D-Day Remembered," May 16 & 17. New Orleans, LA, (402) 371-6633.

May 14 & 15
Mobil East Coast Aerobatic Championships & Open House. Warrenton-Fauquier County Airport, Warrenton, VA, (703) 280-2829.

May 15
Aviation activities to mark opening of flying season. All proceeds go to help museum rebuild after 1993 fire. Canadian Warplane Heritage Museum, (905) 679-4183.

May 28–30
Planes of Fame East Open House. Salute to 8th Army Air Force. Planes of Fame Air Museum, Eden Prairie, MN, (612) 941-2633.

"The Satellite Sky" Update/41

These regular updates to "The Satellite Sky" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

Bremsat	2-3-94 KSC
Progress M-21	1-28-94 TT
Radar targets	2-3-94 KSC
Soyuz TM-18	1-8-94 TT

630 to 1,250 MILES

Meteor 3-6	1-24-94 PL
Tubsat	1-24-94 PL

21,750 to 22,370 MILES

DBS-1	12-18-93 KOU
Gals 1	1-20-94 TT
NATO 4B	12-8-93 CAC
Raduga 31	2-4-94 TT
Telstar 4A	12-15-93 CAC
Thaicom 1	12-18-93 KOU

Deletions

90 to 300 MILES

Cosmos 2223
down 12-16-93

Cosmos 2262
down 12-18-93

Soyuz TM-17
down 1-14-94

Launched but not in orbit

90 to 300 MILES

OREX Japan research	2-3-94	down 2-4-94
STS-60 U.S. research	2-3-94	down 2-11-94

Inoperative but still in orbit

300 to 630 MILES

Cosmos 2195

21,750 to 22,370 MILES

ECS-2

FORECAST

In the Wings...

The Last Outpost of the Cold War. At Kunsan Air Base, a small, inhospitable patch on the west coast of South Korea, U.S. fighter pilots drill for a possible encounter with the puzzling menace to the north. There are few consolations in the life at Kunsan, and they're all in the cockpit of an F-16.

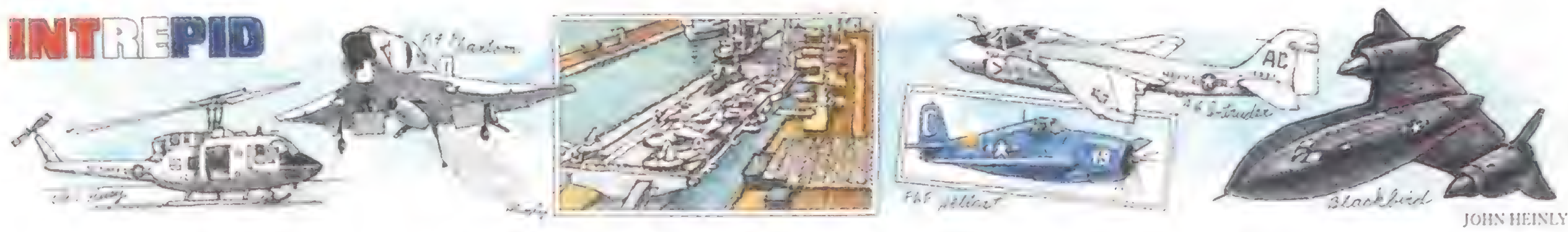
I'd Rather Be Solar Sailing. Chemical rockets are tried and true, and nuclear propulsion will get you there fast, but for some aerospace engineers, the best means of space travel is to hitch a ride on sunlight. U.S. enthusiasts have made a sail and are seeking private funding to launch it.

It Just Feels Wright. The Wright Model B, a fragile craft built in 1911, has been recently reincarnated...twice. Both versions can fly, but the differences between them raise questions about the theory, purpose, and even the ethics of antique reproduction.

Air & Space/Smithsonian *commemorates two historic events in the next issue:*

Fifty Years After D-Day. In the fearsome, complex assault on the beaches of Normandy, Allied victory depended on air, sea, and ground forces working together. The bomber groups flying the Martin B-26 Marauder knew their part, and, though many have questioned the bomber's effectiveness since, the air crews believed they had the right machine for the job.

Twenty-five Years After Apollo 11. Apollo astronauts not only went to the moon, they brought 841.6 pounds of it back. What have scientists learned about the solar system in the 25 years they have been studying the moon rocks?



JOHN HEINLY

A New Life for an Old Carrier

In a city where decrepit police stations are converted to luxury condos and abandoned cathedrals become nightclubs, it's no surprise to find an aircraft carrier that's been metamorphosed into a museum. Docked at New York City's Pier 86 on the Hudson River, the USS *Intrepid* is today a floating collection of artifacts related to aviation, the sea, and space exploration.

Weighing 33,000 tons and measuring 898 feet long, the *Intrepid* itself is the largest exhibit on display. The ship entered action in World War II, and the Japanese tried their best to sink it, hitting it with a total of seven bombs, five kamikaze attacks, and a torpedo.

Today, the target of all that violence is dimly lighted and covered with indoor-outdoor carpeting. Children chase one another through solemn displays of wartime mayhem, while young men try to cover their ignorance of history in front of their significant others. All in all, the *Intrepid* looks much like any other museum. But evidence of its past life is everywhere. The *Intrepid* still smells like an aircraft carrier: hydraulic fluid, rust, diesel fuel, avgas, and sweat. And former *Intrepid* crew members are at work throughout the museum, volunteering their time as restorers and docents.

Commanding the second group is ex-Air Force sergeant Shirley Schultz. In a long denim skirt and Nike running shoes, Schultz gives breathless tours that recount the ship's history: how the *Intrepid* served in World War II, how afterward it was fitted with an angled deck, a British innovation allowing simultaneous takeoffs and landings, how it was the first U.S. carrier whose hydraulic catapults were replaced with more efficient steam catapults, which visitors can check out in Hangar Bay One.

Now called Navy Hall, the bay has a wide-screen theater continuously showing a rousing film called *Air Power at Sea*; it also displays several relatively modern naval airplanes, such as a Grumman A-6 Intruder and a mockup of the F/A-18 Hornet prototype. In the second hangar bay you find Pioneer Hall, which pays homage to the early days of naval aviation, and Intrepid Hall, where exhibits illustrate carrier warfare in the Pacific during the second world war. The aft hangar bay is devoted to undersea and space exploration. Exhibits there show how the *Intrepid* served as the primary recovery vessel for Mercury astronaut Scott Carpenter's off-target Atlantic splashdown in 1962, and for the Gemini 3 flight of John Young and Gus Grissom in 1965. The exhibit also includes mockups of many U.S. space vehicles, such as the Apollo 12 lunar module, named (of course) the *Intrepid*. Though the carrier made three combat tours in Vietnam, little is shown of its service there.

Intrepid *Sea-Air-Space Museum, Pier 86, West 46th St. and 12th Ave., New York, NY 10036. Phone (212) 245-2533. Admission: $7 adults, $6 seniors, $4 kids 6 to 11, no charge for kids under 6. Open 10 a.m. to 5 p.m.; daily from Memorial Day to Labor Day, Wed. through Sun. the rest of the year.*

Toward the end of the Vietnam war, the *Intrepid* was decommissioned. The battered old carrier was headed for the scrap-heap when real estate executive Zachary Fisher learned of the *Intrepid*'s fate. In 1978 Fisher formed a foundation to obtain the ship and turn it into a museum. Four years later, the *Intrepid* was finally berthed at its present home.

The dockside location has allowed the museum to acquire some novel nautical exhibits. Flanking the *Intrepid* are the *Growler*, a submarine that once carried cruise missiles, the *Edson*, a Vietnam-era destroyer, and the *Slater*, a World War II destroyer escort. The *Growler* and *Edson* are open to visitors; the *Slater* will be soon.

Sometimes the museum's locale can be a hindrance: in New York City, anything not bolted down grows legs. Ancient telephone handsets, bits of brightwork, and even pieces of airplanes have all disappeared from the *Intrepid*. Fortunately, the museum was able to replace some of the missing items, and now security guards are posted on the bridge.

Up on the flight deck, schoolchildren wander among a hodgepodge collection of post-World War II aircraft: two F11F-1 Tigers, an FJ-2 Fury, an F3D-2 Skyknight, and an F3H-3 Demon, as well as several helicopters, including a couple of UH-1 Hueys and an H-21C Shawnee. You'll also come across a couple of exhibits that are technically all wrong on a carrier deck but awesome nonetheless, like a Lockheed A-12 Blackbird spyplane and a Soviet MiG-21 fighter jet. The most popular aircraft, however, may well be the Vietnam-era F-4N Phantom II. Says Shirley Schultz: "A lot of airline pilots in New York come here on layover, and they'll tell you, 'When I was a young man, I flew an F-4 like that one.' They come on board just to pay their respects."

As you make your way through the flight deck, you happen on a more somber exhibit: a plaque that marks the spot where 10 men were killed and another 12 injured when a kamikaze pilot flew a Zero into the *Intrepid* during a 1944 attack near the Philippines. All of the victims were black. At the time, blacks could officially serve on the ship only as steward's mates in the galleys and mess halls, but these men had nonetheless volunteered for anti-aircraft gunnery duty.

Much of the *Intrepid* remains closed to the public, awaiting funds for asbestos containment and construction upgrades. In her spare time Schultz likes to prowl those dark, seemingly endless passageways, where great sheets of peeling green and white paint hang like cobwebs and the loudest sound is the echo of water dripping far away. As you venture down one hallway, you pass a locker room door upon which some immortal once painted a bold (though awkward) proclamation: "Through this portal glass [are] the greatest fighter attack pilots in the world."

—Phil Scott

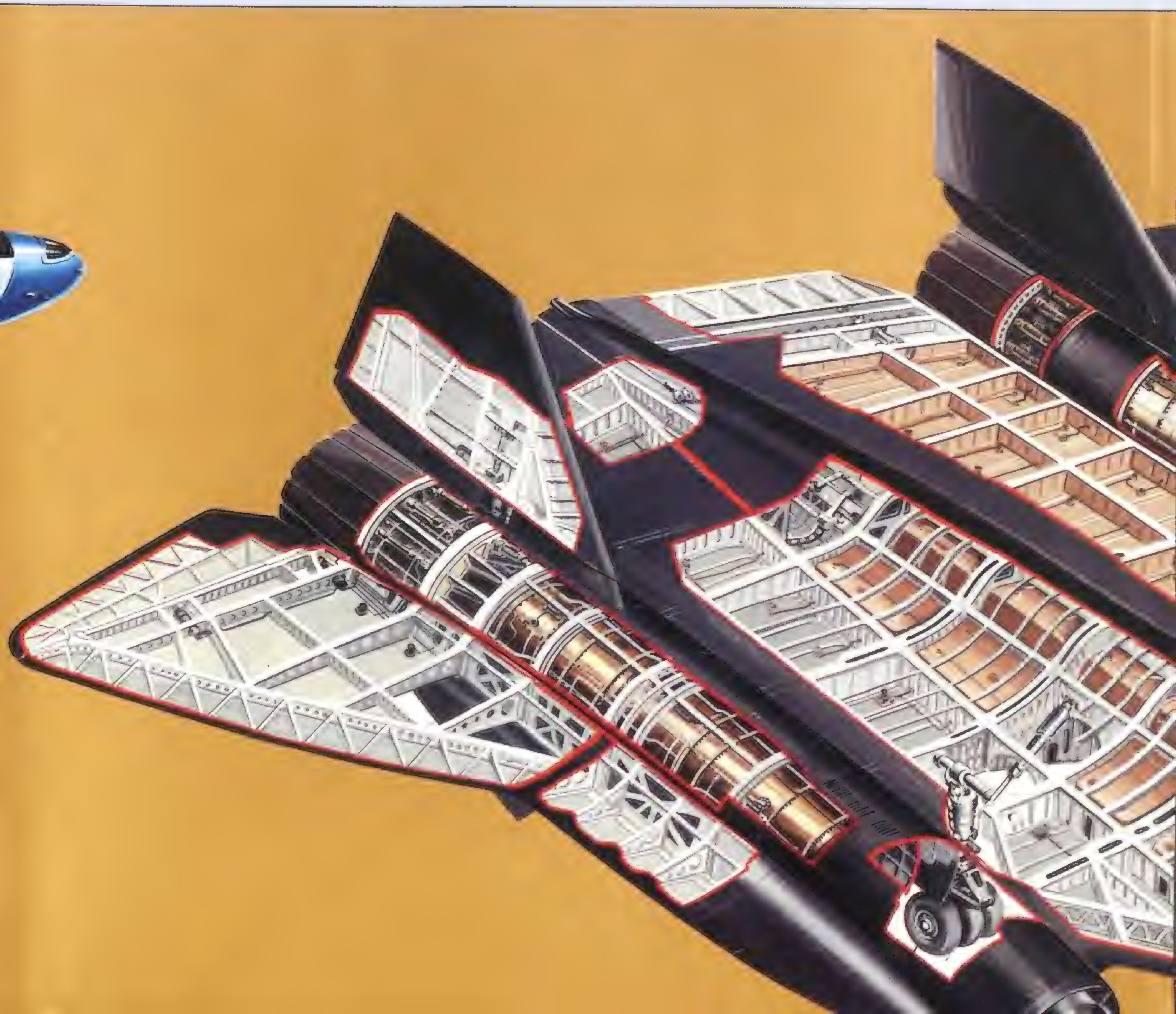
PLANET EARTH
A COMMEMORATIVE EARTH DAY POSTER FROM THE APRIL 1990 SMITHSONIAN

AIR&SPACE
Smithsonian

A supplement to the April/May 1994 issue of *Air&Space/Smithsonian*

The United States' second turbojet-powered fighter, the single-engine XP-80 prototype bested the twin-engine Bell XP-59A. The prototype for the F-80 jet fighter was built in 143 days (37 under schedule) and set the standard for the production of Skunk Works aircraft. The P-80 and its descendants, the T-33 and F-94, took a generation of pilots out of piston-engine cockpits and introduced them to high-speed jet-powered flight. As one of the Air Force's primary fighters in the Korean war, the F-80 Shooting Star became the first jet to down another—a MiG-15.

A gallery of innovative designs from a small group of engineers who mastered the fine art of achieving the impossible.



Aircraft of the

The F-117A is an aerodynamically and aesthetically unorthodox aircraft. Its low radar signature is due in large part to the art of faceting—using flat panels that divert radar reflections. Virtually incapable of stable flight, it borrowed heavily from the General Dynamics F-16 fly-by-wire flight control system. When operating in controlled airspace, the F-117A is equipped with radar reflectors to ensure it appears on air traffic control screens.

Skunk Works

XP-80
First flight January 8, 1944.
Predecessor to the F-80 Shooting Star, the United States' first operational jet fighter and the first American aircraft to surpass 500 mph in level flight.

Model 75 Saturn
First flight June 17, 1946.
Twin-engine regional airliner that incorporated a laminar-flow airfoil and advanced aluminum alloy construction.

XR6O-1 Constitution
First flight November 9, 1946.
Long-range 204-passenger Navy transport to be marketed to airlines.

TP-80C (T-33)/L-245 (T2V-1) SeaStar
First flights March 22, 1948/December 16, 1953.
Two-seat trainer version of the F-80. Navy's T2V-1 was a beefed-up version with improved low-speed performance and stability.

YF-94 Starfire
First flight April 16, 1949.
Enlarged and heavier version of two-seat P-80/T-33 with afterburner, radar, and air-to-air rockets.

XF-90
First flight June 3, 1949.
Penetration fighter and bomber escort constructed of a high-strength aluminum alloy. The design was too heavy for its twin jet engines.

X-7 Ramjet Test Vehicle
First launch April 26, 1951.
Unmanned Mach 3-plus test vehicle for the Marquardt ramjet engine; air-launched from a B-29 with parachute and ground-penetration nose spike to facilitate recovery.

XFV-1
First flight June 16, 1954.
Vertical-takeoff-and-landing turboprop tail-sitter fighter.

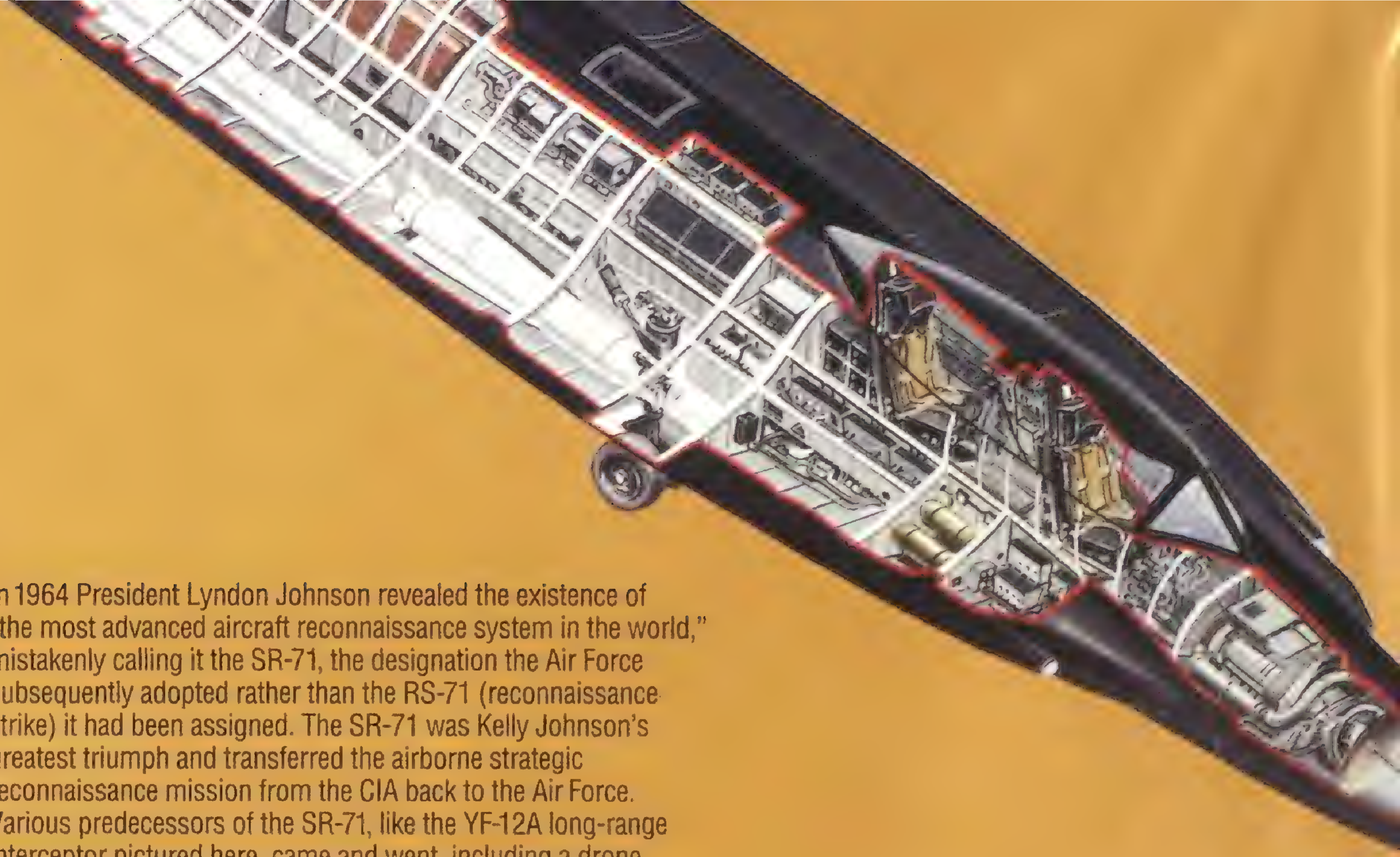
R7V-2/YC-121F Constellation
First flights September 1, 1954/April 5, 1955.
Turboprop version of the Model 1049 Constellation transport.

The XFV-1 was designed to operat
launching and landing vertically an
when airborne. Lockheed test pilot
numerous successful test flights, i
vertical to horizontal flight, but the
be built around never reached the t
Johnson, who was quick to recogr
deemed the XFV-1 "dangerous." N
competitor, Convair's XFY-1, prove

The "U" in U-2 stood for Utility, a Skunk Works attempt to disguise the fact that the aircraft was designed to be a spyplane. Funded by the Central Intelligence Agency, the "Article" cruised at over 70,000 feet, where its Hycon Type B camera, designed by Edwin Land of Polaroid fame, provided images with a resolution of 30 inches. The airplane incorporated bicycle-type landing gear, wingtip "pogos" that dropped off after takeoff, and a lightweight glider-like wing that created so much lift the airplane was difficult to land. U-2s were taken off Soviet overflight duty after Francis Gary Powers was shot down near Sverdlovsk in 1960. Today, U-2R derivatives fly missions for NASA and the Air Force.

from small Navy ships,
transitioning to horizontal flight
Herman "Fish" Salmon made
cluding transitioning from
Allison engine the XFV-1 was to
ightworthy stage, and Kelly
ze a failure in the making,
ither the XFV-1 nor its
practical for combat.

The F-104, with its slender, needle-nose fuselage, razor-sharp wing, and T-tail, was designed to surpass the performance of the swept-wing jet fighters of the Korean war. The nimble Mach 2-plus Starfighter, nicknamed "missile with a man in it," set a number of speed and altitude records in the late 1950s and sold well to NATO countries.



In 1964 President Lyndon Johnson revealed the existence of "the most advanced aircraft reconnaissance system in the world," mistakenly calling it the SR-71, the designation the Air Force subsequently adopted rather than the RS-71 (reconnaissance strike) it had been assigned. The SR-71 was Kelly Johnson's greatest triumph and transferred the airborne strategic reconnaissance mission from the CIA back to the Air Force. Various predecessors of the SR-71, like the YF-12A long-range interceptor pictured here, came and went, including a drone launched from a mother ship. In 1976 an SR-71 set speed (2,193 mph) and altitude (85,068 feet) records that still stand. Today only NASA uses the SR-71; the Air Force retired it in 1990.

RB-69
First flight and operational missions in 1955.
Lockheed P2V Neptunes modified with sensors, jammers, and navigation equipment for Central Intelligence Agency intelligence-gathering missions.

YC-130 Hercules
First flight August 23, 1954.
Four-engine turboprop military transport with large cargo bay and extraordinary short-field takeoff and landing performance.

XF-104 Starfighter
First flight March 4, 1954.
First "lightweight" Mach 2-plus fighter.

U-2
First flight August 4, 1955.
High-altitude long-range reconnaissance aircraft funded by the CIA.

JetStar
First flight September 4, 1957.
Twin-engine military utility and cargo jet designed with an eye toward the commercial transport market.

CL-400
Conceived in January 1956.
Mach 2.5 reconnaissance aircraft fueled by liquid hydrogen. Cancelled in February 1959.

A-12/SR-71
First flights April 26, 1962/December 22, 1964.
Mach 3-plus successor to the U-2 used by CIA over North Vietnam and North Korea in late 1960s. Three long-range interceptor versions, designated AF-12 and later YF-12A, were built and tested.

The SR-71 was a larger and heavier incarnation of the A-12 in which the sensor equipment bay was replaced with a second cockpit for a reconnaissance systems officer.

D-21
First launch March 5, 1966.
Unmanned strategic reconnaissance ramjet-powered Mach 3-plus drone (designated M-21) launched from an A-12 and, later, from a B-52. Cancelled in July 1971 after few successful launches and many failures.

CL-1200 Lancer
Proposed in 1971.
Modification of the F-104 designed to sell primarily to NATO countries. Developed as the X-27 but lost lightweight fighter competition to Northrop and General Dynamics.

Have Blue/F-117A Nighthawk
First flights December 1, 1977/June 18, 1981.
Have Blue Experimental Stealth Testbed was a technology demonstrator with an extraordinarily low radar cross-section and low infrared, acoustic, and visual signatures.

The F-117A was the world's first operational stealth attack aircraft.

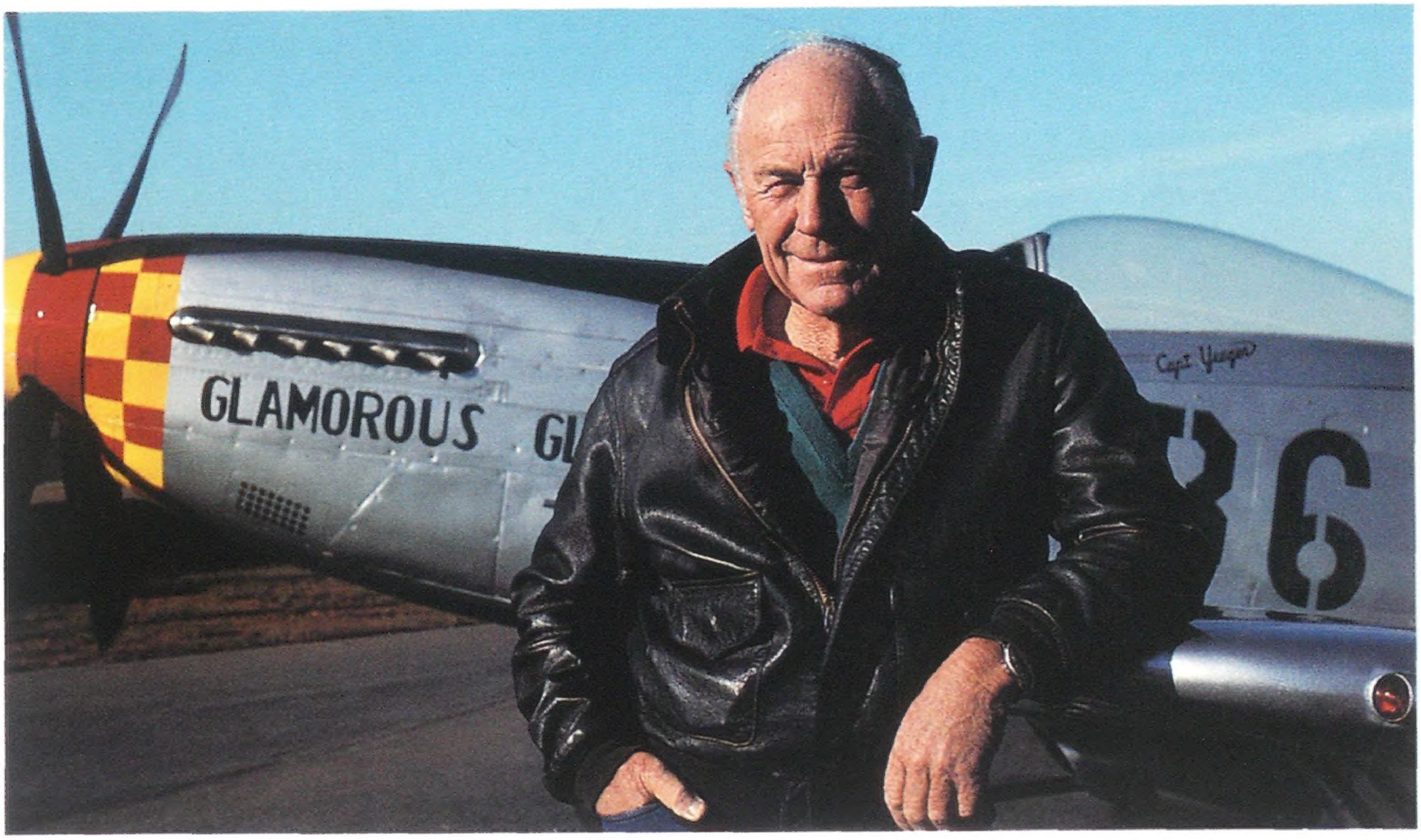
F-22 Lightning II
First flight September 29, 1990.
Developed by the Skunk Works in concert with Boeing and General Dynamics. Lockheed focused on stealth, agility, supersonic cruise without the use of afterburner, high-angle-of-attack capabilities, and missile firing.

Design and production by Phil Jordan
Illustrations by John Batchelor

on

E AND PLYMOUTH

Your Seat Belt.



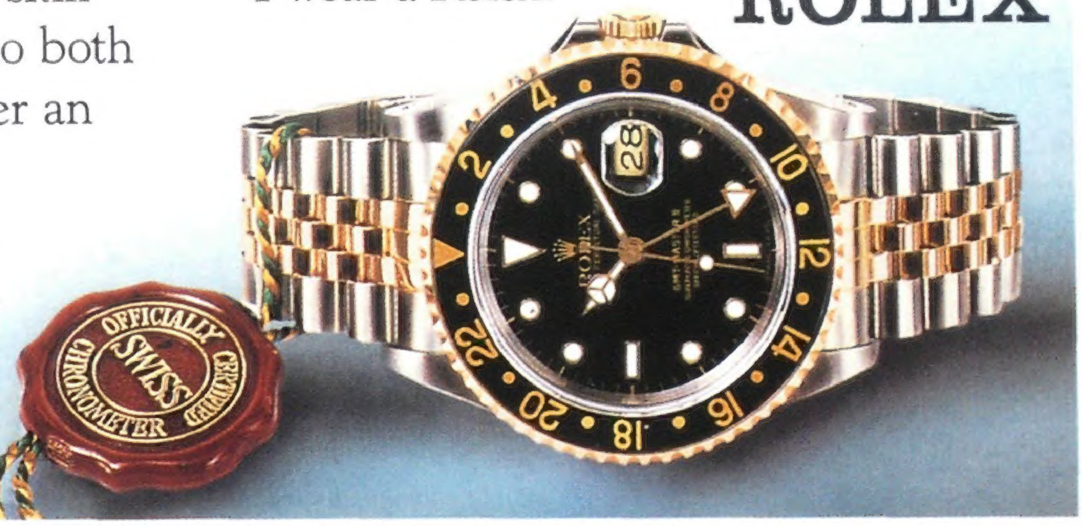
"If you want to grow old as a pilot, you've got to know when to push it, and when to back off." *Chuck Yeager*

Throughout his remarkable career, Chuck Yeager has shown an uncanny talent for what pilots call "pushing the edge of the envelope." At 21, only three years after boarding his first plane, Yeager was leading a squadron of fighter pilots in World War II. And at the age of 24, he became the first person to fly faster than the speed of sound.

Attempting such dangerous feats is one thing. Living to describe them to your grandchildren is another. Displaying the enormous courage, skill and cool judgment needed to do both has made General Chuck Yeager an authentic American hero.

Although retired from the military, Yeager remains a man on the move. He's an avid sportsman with a lifelong love of the outdoors, a lecturer and a consulting test pilot who still loves to fly. "Maybe I don't jump off 15-foot fences anymore," said Yeager, "but I can still pull 8 or 9 G's in a high-performance aircraft." And in all his exploits, Yeager depends on a rugged and reliable timepiece. "I wore a Rolex 40 years ago when I broke the sound barrier and I still do today," says Yeager matter-of-factly. "A pilot has to believe in his equipment. That's why I wear a Rolex."

ROLEX



Rolex Oyster Perpetual GMT-Master II Date Chronometer in stainless steel and 18kt gold with matching Jubilee bracelet.
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